

The introduction of online mathematics assessment as an alternate assessment to facilitate mathematics learning of Senior Phase Deaf and Hard of Hearing Learners

by

Nolan Brandon Damon

Dissertation presented for the Degree of Doctor of Philosophy in the Faculty of Education, at
Stellenbosch University



Supervisor: Dr. Faaiz Gierdien

March 2017

Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof, that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or part submitted it for obtaining any qualification.

March 2017

Copyright © 2017 Stellenbosch University of Stellenbosch

All rights reserved

ABSTRACT

The difficulties Deaf and H/H learners experience during paper and pencil mathematics assessments as a result of reading, interpretation and language obstacles result in their poor performance in school mathematics. Although assessment accommodation and alternate assessments are prescribed by state policies to eliminate these barriers written tests present, it is limited to read aloud and signed instructions.

The primary objective of this study was to determine whether Online Mathematics Assessment (OMA) as an alternate assessment for Deaf and Hard of Hearing Learners in the Senior Phase can eliminate obstacles written mathematics tests present. To achieve this goal; it was necessary to investigate the critical characteristics of OMA specifically those that might provide teachers with insights into the cognitive functions of Deaf and H/H learners. Also, such an OMA should possess specific attributes to mediate the learning processes of these students and to eliminate the obstacles paper and pencil assessments present. The OMA were designed making use of the quiz module in Moodle as well as WIRIS and GeoGebra plugins. These test items were based on the function concept and constructed in line with CAPS (2011).

The particular learning theories which had the capacity to promote mediation and knowledge construction i.e. Mediated Learning Experience and Socio-Constructivism were utilized within this study. Moreover, this study adopted a qualitative approach to research and used the different cycles of a Participatory Action Research. The empirical data accumulated during this research study included a variety of data collection techniques. The methods employed consisted of interviews, journal entries, student files and field notes. These text units were transcribed and analyzed making use of a qualitative data analysis software called MAXQDA. Through an in-depth analysis of the text units, three main categories surfaced which included Characteristics of OMA, Mediating the learning process and Potential pitfalls. The findings suggest that OMA has the potential to provide teachers with insights into the cognitive functions and dysfunctions of Deaf and H/H learners, and the mediational attributes can enhance these students' understanding of the function concept.

KEYWORDS: Mathematics assessment, online mathematics assessment, Alternate assessment.

OPSOMMING

Lees, interpretasie en taal probleme wat Dowe en Hardhorende leerders ondervind met geskrewe wiskunde assessering word as 'n direkte rede beskou hoekom hierdie leerders swak doen in wiskunde. Alhoewel assessering akkommodasie en alternatiewe assessering voorgeskryf word deur regeringsbeleide word dit beperk tot hardop lees en Gebaretaal te gebruik om vrae te verduidelik.

Die hoof doel van hierdie studie was om vas te stel of aanlyn wiskunde assessering gebruik kan word as 'n alternatiewe assessering vir Dowe en Hardhorende leerders in die Senior fase. Ten einde hierdie doel te bereik was dit noodsaaklik om die kritiese eienskappe van aanlyn wiskunde assessering te ondersoek, spesifiek daardie wat onderwysers meer insae sal verskaf aangaande die kognitiewe funksies van Dowe en Hardhorende leerders. Tesame moet hierdie aanlyn wiskunde assessering ook die bemiddeling van onderrig en leer prosesse van Dowe en Hardhorende leerders kan bewerkstellig en sodoende die obstruksies wat geskrewe wiskunde assessering bied uit die weg ruim. Hierdie aanlyn wiskunde assessering was ontwerp deur gebruik te maak van die toets module in Moodle sowel as die WIRIS en GeoGebra toevoegings. Hierdie toetse was gebaseer op die funksie begrip wat in lyn is met die KABV (2011).

Die spesifieke leerteorieë wat die vermoë het om bemiddeling en kennis konstruksie te bevorder, o.a. Bemiddel Leerervaring en Sosio-Konstruktivisme is gebruik in hierdie studie. Verder het hierdie studie 'n kwalitatiewe benadering van navorsing gevolg en spesifiek die siklusse van Deelnemende Aksienavorsing gebruik. Empiriese data is ingewin deur die gebruik van verskillende data versamelings tegnieke o.a. persoonlike onderhoude, joernaal inskrywings, student leers en veldnotas. Hierdie teks eenhede is getranskibreer en geanaliseer deur gebruik te maak van 'n kwalitatiewe data ontledings sagteware genoem MAXQDA. Deur 'n in diepte analiese van die teks eenhede het drie kategorieë opgeduik o.a. Eienskappe van aanlyn wiskunde assessring, Bemiddeling van die leerproses en Moontlike slaggate. Die bevindinge stel voor dat aanlyn wiskunde assessering oor die vermoë beskik om onderwyser insigte te verskaf oor die kognitiewe funksies en disfunksies van Dowe en Hardhorende leerders en die bemiddelings kenmerke wat dit oor beskik kan hierdie leerders se begrip van die funksie konsep verbeter.

SLEUTELWOORDE: Wiskunde assessering, Aanlyn wiskunde assessering, Alternatiewe assessering.

ACKNOWLEDGMENTS

All the praise and all the glory goes to God Almighty, for without Him, this dissertation would not have been possible. He gave me strength when I was weak; He showed me the way when lost and He gave me insight when I prayed for wisdom.

All my thanks to Dr. Faaiz Gierdien for his continuous support and motivation and for always giving me positive feedback and input. I am grateful for his insightful comments and for keeping me focused and on track.

My sincere appreciation goes to my wife, Selesty-Kay and my sons, Keanu, and Nevan, for all your prayers, support and motivation. Thank you for giving me the time and space to complete this dissertation.

Nolan Brandon Damon

STELLENBOSCH

March 2017

DEDICATIONS

I dedicate this Doctoral dissertation to my wife, Selesty-Kay and my two sons, Keanu and Nevan, who supported me throughout the writing of this thesis and who patiently assisted me with words of assurance and encouragement.

TABLE OF CONTENTS

TABLE OF CONTENTS.....	vi
LIST OF FIGURES	xiii
LIST OF TABLES	xvi
LIST OF ABBREVIATIONS.....	xviii
CHAPTER 1: INTRODUCTION	1
1.1 Background.....	3
1.1.1 Regulations pertaining assessment accommodation and alternate assessment.....	5
1.1.2 The effects of hearing impairment on mathematics education	10
1.1.3 Mathematics assessment set out by CAPS.....	11
1.1.4 The rationale for computer-based assessment specifically for Deaf and H/H learners	13
1.2 Aim of the study.....	14
1.3 Statement of the problem	15
1.4 Research Question	16
1.5 Research Methodology	16
1.5.1 Sampling	17
1.5.2 Data collection	17
1.6 Key concepts	18
1.6.1 Mathematics assessment	18
1.6.2 Online mathematics assessment.....	19
1.6.3 Alternate assessment.....	19
1.7 Provisional Chaptering.....	19
1.8 Ethical considerations	21
1.8.1 Ethical clearance	21
1.8.2 Confidentiality	22
1.9 Potential risks and discomforts	23
CHAPTER 2: LITERATURE REVIEW	25
2.1 Introduction.....	25
2.2. Background	26
2.3 The purpose of assessment.....	26
2.4 The principles of assessment	27
2.5 Guidelines pertaining excellent assessment practices.....	30

2.5.1 Reliability.....	30
2.5.2 Fairness	30
2.5.3 Validity	31
2.5.4 Discrimination.....	31
2.5.5 Meaningfulness and contributing to learning	31
2.6 Norm-referenced and Criterion-referenced assessments	32
2.7 Different types of assessments.....	33
2.7.1 Formative assessment	34
2.7.2 Summative assessment.....	34
2.8 School-based Assessment	35
2.8.1 The Assessment content presented by CAPS	38
2.8.2 Mathematical Functions.....	38
2.8.3 The function concept as prescribed by CAPS.....	42
2.9 Assessing students who experience learning disabilities.....	44
2.10 Assessment concessions.....	45
2.11 Assessment accommodation	46
2.11.1 Different categories of assessment accommodations	46
2.11.2 Different types of assessment accommodations	47
2.12 Assessment accommodation in practice	49
2.13 Alternate Assessment.....	52
2.13.1 The origin of Alternate Assessment.....	52
2.13.2 Alternate assessment defined	52
2.13.3 Alternate assessment prescribed by the NPA	54
2.13.4 Different types of alternate assessments	55
2.13.5 Alternative measures in SA	57
2.14 Assessment accommodation versus Alternate Assessment	66
2.15 Summary.....	66
CHAPTER 3: LEARNING THEORIES SPECIFIC TO DEAF/HH LEARNERS AND ICTS...	68
3.1 Introduction.....	68
3.2 How Deaf students learn.....	68
3.2.1 Deafness	68
3.2.2 Hard of Hearing	70

3.3 Mathematics teaching and learning in the case of Deaf and H/H learners	70
3.3.1 Informal learning	71
3.3.2 Teaching methods	71
3.3.3 The language of communication and instruction	71
3.4 Learning theories specific to mathematics education	73
3.4.1 Constructivism	74
3.4.2 Social Constructivism	76
3.5 Absolutist philosophy	77
3.5.1 Absolutist learning approach	78
3.5.2 Absolutist teaching approach	78
3.6 The philosophy of Fallibilism	78
3.6.1 Fallibilist learning approach	79
3.6.2 Fallibilist teaching approach	80
3.7 Feuerstein and learning	80
3.7.1 Instrumental Enrichment (IE)	81
3.7.2 Structural Cognitive Modifiability (SCM)	82
3.7.3 Dysfunction in the input phase	85
3.7.4 Dysfunction in the elaboration phase	85
3.7.5 Dysfunction in the output phase	86
3.8 Mediated Learning Experience (MLE)	86
3.8.1 Direct Learning Experience and Mediated Learning Experience	88
3.8.2 The characteristics of MLE	89
3.9 Computer-mediated learning environments	93
3.10 Summary	96
CHAPTER 4: ONLINE MATHEMATICS ASSESSMENT FEATURING MOODLE AND	
WIRIS	97
4.1 Introduction	97
4.2 Online Mathematics Assessment (OMA)	97
4.2.1 Definitions	97
4.2.2 Rationale behind the use of OMA	98
4.2.3 Different views on OMA	99
4.3 Ethical considerations of online assessment	102
4.3.1 Protect access to the test/exam	103

4.3.2 Track interaction	103
4.3.3 Randomization of questions.....	103
4.4 Validity	104
4.5 Reliability.....	105
4.6 Online assessment for Deaf and H/H learners	106
4.7 Moodle	108
4.7.1 Moodle-based activities	110
4.7.2 Moodle Quizzes	112
4.7.3 Plugins in Moodle	114
4.7.4 Mathematical notations.....	114
4.8 WIRIS	115
4.8.1 WIRIS CAS	116
4.8.2 WIRIS Editor	116
4.8.3 WIRIS Quizzes	116
4.8.4 WIRIS Plugin.....	117
4.8.5 Research on the use of WIRIS	118
4.8.6 Feedback within quizzes	120
4.8.7 Reporting quiz results	121
4.9 Summary	122
CHAPTER 5: METHODOLOGY	123
5.1 Introduction.....	123
5.2 Research design	123
5.3 Research philosophy	123
5.3.1 Ontology	124
5.3.2 Epistemology	124
5.4 Qualitative research	125
5.5 The Rationale for choosing QR	125
5.6 Research Strategy.....	126
5.6.1 Participatory Action Research	126
5.6.2 The roots of PAR	128
5.6.3 Principles of PAR	129
5.6.4 Characteristics of PAR.....	131

5.6.4.4 PAR as dynamic.....	136
5.6.4.5 PAR as developmental.....	137
5.6.4.6 PAR as critical	137
5.7 Strengths of PAR	137
5.8 Challenges of PAR.....	138
5.8.1 Developing equal partnership	138
5.8.2 Waiving your control and manipulation as the research specialist.....	139
5.8.3 Continuance of the PAR process	139
5.8.4 Unplanned effects of PAR	139
5.9 PAR as an empowerment endeavor	140
5.9.1 Raising consciousness.....	140
5.9.2 Liberating participants	140
5.9.3 Learning	141
5.9.4 Fortifying participants' problem solving capabilities	142
5.10 The rationale for choosing PAR	142
5.11 Site selection and sampling of target population	144
5.12 The role of the teacher-researcher.....	146
5.13 Data Collection methods.....	146
5.13.1 Focus groups	147
5.13.2 Participant observation.....	148
5.13.3 Interviews.....	149
5.14 Data Analysis Framework.....	150
5.15 Data validation	151
5.15.1 Methodological triangulation.....	152
5.16 Delineating the limitations of the current research study	153
5.17 Summary	154
CHAPTER 6: ANALYSIS AND FINDINGS OF THE CURRENT RESEARCH STUDY	155
6.1 Introduction.....	155
6.2 Analysis of the data.....	155
6.3 Findings.....	156
6.3.1 The interviews, journal entries and field notes based on Deaf and H/H learners' interaction with the OMA	156
6.4 PAR cycle	162

6.4.1 Observation	163
6.4.2 Reflection	163
6.5 Plan 1	164
6.5.1 Action.....	164
6.5.2 Observation	164
6.6 Findings based on the interviews, journal entries and field notes based on Plan 1	167
6.6.1 Category 1: Characteristics of OMA	168
6.6.2 Category 2: Mediating the learning process	171
6.6.3 Category 3: Potential pitfalls	174
6.7 Reflection (interpret the findings).....	180
6.7.1 Characteristics of OMA	180
6.7.2 Mediating the learning process	180
6.7.3 Potential pitfalls	181
6.8 Plan 2	181
6.8.1 The Universal Designed Assessment (UDA)	182
6.9 Protocols to maintain the ethics	189
6.9.1 Fairness	189
6.9.2 Validity	190
6.9.3 Reliability.....	190
6.9.4 Discrimination.....	190
6.9.5 Meaningfulness in contributing to learning	191
6.10 Modifications made to the OMA	192
6.10.1 Screen layout modifications.....	192
6.10.2 Solving WIRIS problems.....	193
6.10.3 Increased accessibility	194
6.11 Action (implement plan 2)	195
6.12 Observation (what worked/ did not work)	195
6.13 Findings based on the interviews, journal entries and field notes based on Plan 2	199
6.14 Reflection (interpret and analyze findings).....	200
6.15 Plan 3	200
6.16 Action (implement plan 3)	212
6.17 Observation	212

6.18 Findings based on the interviews, journal entries and field notes	215
6.19 Reflection (interpret and analyze findings).....	215
6.20 Conclusion	216
6.21 Discussion	217
6.21.1 Taxonomies.....	217
6.21.2 Mediated Learning Experience	228
6.21.3 Operational challenges of OMA	237
6.21.4 Implications for teachers.....	241
6.21.5 Implications for Deaf and H/H learners.....	245
6.22 Summary.....	246
CHAPTER 7: CONCLUSION AND RECOMMENDATIONS	247
7.1 Introduction.....	247
7.2 Summary of the research project	247
7.3 Limitations of this study	250
7.4 Possible recommendations for future research	250
Addendum A (Research approval from the Research Ethics Committee, US)	252
Addendum B (Research approval letter from WCED)	254
Addendum C (Research approval letter from the SGB, Nuwe Hoop Centre)	255
Addendum D (Consent to participate in the research study, US)	256
Addendum E (Participation information leaflet and assent form)	261
References.....	264

LIST OF FIGURES

Figure 2.1: Different types and techniques of assessment set out by the NCS (DBE, 2011)	34
Figure 2.2: An example of the facets and layers of mathematical functions (Adapted from: DeMarios & Tall, 1999:687)	37
Figure 4.1: MathJax equation editor in Moodle	105
Figure 5.1: The PAR Cycle. (Adopted from Crane & O'Regan, 2010:11)	128
Figure 5.2: Extended PAR Cycle. (Adapted from Crane & O'Regan, 2010:14)	129
Figure 5.3: The methodological triangulation utilized in the current research project [Adapted: Denscombe, 2010:351]	146
Figure 6.1: Screenshot of all the data captured in MAXQDA	152
Figure 6.2: The coded segments within each document within MAXQDA	153
Figure 6.3: Code relations browser within MAXQDA	153
Figure 6.4: The code distribution in all the documents within MAXQDA	154
Figure 6.5: Further analysis of the text categories and subcategories in MAXQDA	155
Figure 6.6: Assessment results of learners doing the OMA	158
Figure 6.7: TU of plan one as coded in MAXQDA	159
Figure 6.8: Code relation browser within MAXQDA	160
Figure 6.9: An example of the video feedback within the OMA	165
Figure 6.10: How the principle of amenable to accommodation was obtained in this research project	176
Figure 6.11: An illustration of unnecessary information within the question	183
Figure 6.12: An example of the zoom in plugin where only the question is visible	183
Figure 6.13: An illustration of an interactive video as a practice exercise	184

Figure 6.14: Plan 2 of the OMA results	186
Figure 6.15: TU of plan two as coded in MAXQDA	187
Figure 6.16: Code relation browser within MAXQDA	187
Figure 6.17: Situated task created in GeoGebra	192
Figure 6.18: High-level complexity of elements in the OMA	193
Figure 6.19: An illustration of a realistic view of input and output values from a function machine	194
Figure 6.20: Interactive mathematics content which changes through responses by learners	195
Figure 6.21: The polytomous scoring model used in the OMA	198
Figure 6.22: The dichotomous scoring model used in the OMA	199
Figure 6.23: Phase 3 of the OMA results	200
Figure 6.24: TU of plan three as coded in MAXQDA	201
Figure 6.25: Code relation browser within MAXQDA	201
Figure 6.26: Plans 1 – 3 OMA scores of learners	204
Figure 6.27: An illustration of the facets and layers model of user 01	218
Figure 6.28: An illustration of the facets and layers model of user 02	220
Figure 6.29: An illustration of the facets and layers model of user 03	221
Figure 6.30: An illustration of the facets and layers model of user 04	222
Figure 6.31: An illustration of the facets and layers model of user 05	223
Figure 6.32: An illustration of the facets and layers model of user 06	224
Figure 6.33: An illustration of the facets and layers model of user 07	225
Figure 6.34: An illustration of the facets and layers model of user 08	226
Figure 6.35: An example of an interactive question type included in the OMA	229

Figure 6.36: An example of the mediation of meaning incorporated into the OMA	230
Figure 6.37: Badges linked to the OMA in Moodle	231
Figure 6.38: An example of mediated regulation and control of behavior embedded into the OMA	232
Figure 6.39: An example of mediation of individuation and psychological differentiation within the OMA	233
Figure 6.40: An illustration of mediation of goal seeking and goal setting within the OMA	234
Figure 6.41: An example of one of the most complex questions learners had to answer	235
Figure 6.42: The TPACK model representing the body of knowledge required by teachers to integrate technology into their subject matter [Adopted: Koehler & Mishra, 2007:63]	241

LIST OF TABLES

Table 1.1: Alternate assessments recommended by the INCA	7
Table 1.2: Suggested assessment accommodation for learners with disabilities [Adopted: WCED Circular: 0017/2016]	8
Table 2.1 Norm referenced and criterion referenced assessment: adapted from the “criteria and guidelines for assessment of NQF registered unit standards and qualifications” (SAQA, 2001:25)	29
Table 2.2: The weighting of the SBA and End of the year exam prescribed by CAPS (DBE, 2011)	33
Table 2.3: Support measures to provide learners with BTL access to assessment practices. Adapted from DoE (2008)	54
Table 5.1: Personal information of Grade 8 Deaf and H/H students, relating to them hearing loss	139
Table 6.1: The stages, procedures and the software that was used during the data analysis process	150
Table 6.2: Categories and subcategories that emerged through analyzing the interviews, journal entries, and field notes within MAXQDA	155
Table 6.3: The categories and subcategories identified within MAXQDA for Plan 1	160
Table 6.4: The measures that were implemented to minimize the learning barriers	170
Table 6.5: Maximum readability and comprehensibility maintained in the current research study [Adapted: Brown, 1999:4]	177
Table 6.6: The maximum legibility achieved in this research project [Adapted: Thompson, Thurlow & Malouf, 2004:9]	178
Table 6.7: The categories and subcategories identified within MAXQDA for Plan 2	188
Table 6.8: The categories and subcategories identified within MAXQDA for Plan 3	202
Table 6.9: Comparison between Bloom’s (1956) and Anderson	

and Krathwohl's (2001) taxonomy.....	205
Figure 6.10: The DOK model as integrated with the various functions and roles. [Adapted: Hess et al., 2009:4]	208
Figure 6.11: Hess' Cognitive Rigor Matrix as implemented in this research study [Adapted: Hess, 2006:5]	211
Table 6.12: An illustration of the DOK levels for the OMA	215
Table 6.13: Cognitive rigor of Deaf and H/H Grade 8 learners based on the OMA	216
Table 6.14: Minimum and recommended database server requirements [Adapted: Moodle, 2016]	237
Table 6.15: Client-side Web browser requirements [Adapted: Moodle, 2016]	237
Table 6.16: Other requirements to run Moodle	239

LIST OF ABBREVIATIONS

ANA	Annual National Assessments
AMA	Alternate or Adaptive Methods of Assessment
ASL	American Sign Language
CAPS	Curriculum and Assessment Policy Statement
CAS	Computer Algebra System
CBA	Computer-Based Assessment
CMLE	Computer Mediated Learning Environment
CR	Constructed Response
CRM	Cognitive Rigor Matrix
DBE	Department of Basic Education
DCF	Deficient Cognitive Functions
DLE	Direct Learning Experience
DoE	Department of Education
DOK	Depth of Knowledge
FET	Further Education and Training
FIE	Feuerstein's Instrumental Enrichment
GETC	General Education Training Certificate
GIF	Graphics Interchange Format
H/H	Hard of Hearing
ICT	Information and Communication Technology
IDEIA	Individuals with Disabilities Education Improvement Act
IE	Instrumental Enrichment

IEP	Individualized Education Program
INCA	International Review of Curriculum and Assessment Frameworks
IT	Information Technology
LMS	Learning Management System
MAXQDA	MAX Qualitative Data Analysis
MLE	Mediate Learning Experience
MOODLE	Modular Object-Orientated Learning Environment
NCLB	No Child Left Behind
NCS	National Curriculum Statement
NCTM	National Council of Teachers of Mathematics
NCV	National Certificate Vocational
NPA	National Protocol for Assessment
NPPP	National Policy Pertaining to Progression and Promotion
NSC	National Senior Certificate
OF	Overall Feedback
OLP	Online Proctor System
OMA	Online Mathematics Assessment
OU	Open Universities
PAR	Participatory Action Research
PCK	Pedagogical Content Knowledge
PPA	Paper and Pencil Assessment
QR	Qualitative Research
SAQA	South African Qualifications Authority Act
SASL	South African Sign Language

SBA	School-Based Assessment
SC	Senior Certificate
SIAS	Screening, Identification and Support
SCM	Structural Cognitive Modifiability
TCK	Technological Content Knowledge
TPACK	Technology, Pedagogy and Content Knowledge
TPK	Technological Pedagogical Knowledge
TU	Text Unit
UDA	Universal Designed Assessment
USADoE	USA Education Department
VLE	Virtual learning Environment
WCED	Western Cape Education Department
ZPD	Zone of Proximal Development

The introduction of online mathematics assessment as an alternate assessment to facilitate mathematics learning of Senior Phase Deaf and Hard of Hearing Learners

CHAPTER 1: INTRODUCTION

“Children with disabilities are included in general state and district-wide assessment programs, with appropriate accommodations, where necessary [Sec. 612 (a) (16) (A)]. The term ‘individualized education program’ or ‘IEP’ means a written statement for each child with a disability that is developed, reviewed, and revised in accordance with this section and that includes...a statement of any individual modifications in the administration of state or district-wide assessments of student achievement that are needed in order for the child to participate in such assessment; and if the IEP team determines that the child will not participate in a particular state or district-wide assessment of student achievement (or part of such an assessment), a statement of why that assessment is not appropriate for the child; and how the child will be assessed” [Sec. 614 (d) (1) (A) (V) and VI] Individuals with Disabilities Education Improvement Act of 2004 (IDEA, 2004).

“...the participation in such assessments of all students [Sec. 1111 (3) (C) (i)]. (The term ‘such assessments’ refers to a set of high-quality, yearly student academic assessments.) The reasonable adaptations and accommodations for students with disabilities—as defined under Section 602(3) of the Individuals with Disabilities Education Act—necessary to measure the academic achievement of such students relative to state academic content and state student academic achievement standards” [Sec. 1111 (3) (C)(ii)] No Child Left Behind Act of 2001(NCLB,2001).

“...alternate assessments provide a mechanism for learners with the most significant cognitive disabilities, and for other learners who experience barriers to learning who may need alternate ways in which to demonstrate whether they have attained knowledge, concepts and skills” (NPA, 2011).

The above excerpts from international and national policy documents provide a framework for the adaptation of any form of assessment for learners with disabilities. Every school, whether special schools or district schools, should adhere to these policy documents by either implementing assessment accommodation or alternate assessment to provide learners with disabilities a fair chance to showcase what they have achieved. Similarly, Deaf and Hard of Hearing Learners need assessment accommodation and alternate assessment to participate in any

form of evaluation (Qi & Mitchell, 2007). On the one hand, assessment accommodation is intended to remove any obstacle that might hinder a learner from accessing an assessment. In other words, every student irrespective of their disability needs a fair chance to showcase their academic abilities. On the other hand, alternate assessment modifies the format of the evaluation and can provide learners access to any form of assessment (Qi & Mitchell, 2007).

Different assessment accommodations exist in the case of Deaf and H/H students. These include extended time, frequent breaks, separate room, single administration, mark answers in the booklet, interpreter for directions, signed question response, read aloud, dictate/sign response for a scribe, computers and large print (Cawthon, 2006; Cawthon, 2011; Tindal and Fuchs, 1999). The most commonly used assessment accommodation, especially in a South African context, to bridge the gap between the language of the assessment (Afrikaans/English) and the learners' difficulty in interpreting the written assessments, is the use of Sign language. Although this is only the case with formative assessments and no formal research has been conducted on the impact Sign Language, as an evaluation concession has on the performance of Deaf and H/H learners in a South African context.

Different forms of alternate assessments exist in the case of Deaf and H/H students. These include out-of-level testing, checklist, student work samples, curriculum-based alternative, portfolios, observation in a structured setting and observation in an unstructured setting (Cawthon, 2006; Cawthon, 2011). In South Africa, mechanisms for alternate assessments are being regulated by state assessment policies and guidelines for assessment of the National Protocol for Assessment Grades R-12 (NPA, 2011). These mechanisms include a) Alternate Assessments Based on Alternate Attainment of Knowledge (content, concepts, and skills), b) Alternate Assessment Based on Modified Attainment of Knowledge (content, concepts and skills) and c) Alternate Assessments Based on Grade-level Attainment of Knowledge (content, concepts and skills). Accordingly, this research project is in line with Alternate Assessments Based on Grade-level Attainment of Knowledge (content, concepts, and skills). This type of assessment provides a mechanism “for learners with disabilities or learning difficulties who need testing formats or procedures that provide them with equal opportunities to demonstrate their attainment of content which is at the same grade-level as the general assessment” (NPA,

2011:36). Unfortunately, to my knowledge, no forms of online assessment as an alternate assessment are being used in schools for the Deaf and H/H in South Africa, let alone online mathematics assessment as a form of alternate assessment. Moreover, no particular direction is given to schools on what online mathematics assessment as an alternative assessment should look like, how to administer it and how to score it.

To comprehend which alternate assessment to use one has to understand the conditional relation of being Deaf or H/H and how it affects mathematics education. My point here is that being Deaf, and H/H have particular implications for mathematics learning, i.e. language, reading and comprehension difficulties. These difficulties have a direct impact on Deaf and H/H learner's mathematics education. Accordingly, difficulties in mathematics education result in Deaf and H/H students obtaining low scores in mathematics assessments (Pagliaro, 2006; Kelly, Lang, and Pagliaro, 2003, Frostad, 1999 & Nunes and Moreno, 1998). Therefore, some intervention should be put in place to assist Deaf and H/H students in their struggle due to conditional relations. For this reason, the current research study proposes an online mathematics assessment as an alternate assessment. The next section will discuss these dependent relations in more detail.

1.1 Background

Any form of assessment prescribed by CAPS (DBE, 2011) presumes that all learners are proficient in Afrikaans/English, although this isn't the case for Deaf and H/H students. This presumption produces particular problems for students who are Deaf and H/H including: "difficulties with Afrikaans/English, diverse modalities of communication, deficient reading skills, culturally-related experiential differences and test validity and reliability" Rudner (1978 in Gordon & Stump, 1996:236). In other words, Deaf and H/H learners do not have full access to Afrikaans or English across all situations, since it is auditory based (Case, 2005).

Deaf and H/H learners cannot perceive speech and oral communication in the absence of some form of accommodation. Therefore, these learners lack "crucial developmental milestones and experiences that benefit students without hearing loss" (Case, 2005:3). In other words, these pupils embark their schooling with delays in the development of Afrikaans/English as well as a

deficiency in their understanding of Afrikaans/English. Because formal assessment tasks are pencil and paper based, having limited language skills places them at a disadvantage. Essentially, it also means that Deaf and H/H learners, learning Sign Language, is the same as learning Afrikaans as a second additional language. Case (2005:4) concludes that when you “consider the expressive and receptive modalities of deaf or hard of hearing students, which differ significantly from those of English/Afrikaans-based hearing students,” the need for accommodation and alternate assessment becomes even more apparent.

Deaf and H/H learners use different modalities for teaching and learning. These include oral, sign language and total communication. On the one hand, the oral approach makes use of teaching Deaf and H/H learners to speak or lip read. On the other hand, making use of sign language for communication includes signed Afrikaans/English or sign language. Finally, the total communication approach makes use of sign language and speech. However, Deaf and H/H learners are forced to use Afrikaans for reading and writing, because an accepted format of Afrikaans sign language does not exist. Moreover, the distinction between Afrikaans/ English grammar and structure and sign language differs, which further strengthens the need for accommodation. Since these modalities are so diverse, mathematics assessment, especially in written form, becomes extremely difficult and hence the need for alternate assessment.

Difficulties in understanding Afrikaans and thus having limited access to Afrikaans grammar and structure might bring forth reading difficulties. Also, having reading difficulties can present significant obstacles, especially where mathematics text is concerned. These findings are in line with Traxler’s (2000) research which concludes that Deaf and H/H learners lag behind their hearing peers in mathematics performance of about three years. Further detailed discussions on this issue will be elaborated on in chapter 2.

Feuerstein, Rand, Hoffman and Miller (1980) highlight the crucial role culture plays in learners’ active higher order thinking processes. These researchers posit that culture plays an important part in the teaching and learning. They argue that the use of cultural artifacts is conducive to mathematics education, particularly when Deaf and H/H learners are concerned. In line with mathematics teaching and learning in the case of Deaf and H/H, they need sign language,

developed at home as well as in the mathematics classroom. However, for most learners, this is a luxury, particularly when parents or teachers do not use sign language and thus excludes the Deaf and H/H students from these cultural artifacts. Further discussions on these debates will follow in chapter 2.

The next section covers the relevant policy statements on Deaf and H/H learners as well as policy statements specific to mathematics teaching and learning for Grade 8 Deaf and H/H students.

1.1.1 Regulations pertaining assessment accommodation and alternate assessment

In line with the National Policy Act 1996, the Minister of Education decides on the national norms and standards of education as well as assessment. Schools in South Africa who wish to administer assessment accommodation and alternate assessment (concessions), must apply for it in advance through the Council for Quality Assurance in General and Further Education and Training (WCED, circular:0021/2009). Umalusi also monitors the quality of these assessment accommodations. The Umalusi Council is responsible for developing and supervising the standards for General and Further Education and Training, which must comply with the National Qualifications Framework Act No 67 of 2008 and the General and Further Education and Training Quality Assurance Act No 58 of 2001. They are also responsible for the certification of the Senior Certificate (SC) and the National Senior Certificate (NSC), National Technical Certificate (N3), National Certificate Vocational (NCV) and the General Education Training Certificate: Adults (GETC). Also, they “develop and evaluate qualifications and curricula to ensure that they are of the expected standard, moderate assessment to make sure that it is fair, valid and reliable, accredit providers of education and training and evaluation, conduct research to ensure educational quality and verify the authenticity of certificates” (Umalusi, 2015:1). However, Education White Paper 6 of 2001 provides a framework for education and assessment practices in Special schools which focus on “Assessment processes will address barriers to learning and current policies and practices will be reviewed and revised to ensure that the needs of all learners are acknowledged and addressed” (p.33).

Furthermore, circular:0021/2009, which focuses on the Processes and Procedures for Exemptions and Concessions in Grade 9, states that “in most cases, the learner will be allowed additional time or any other alternative or adapted method of examining in order to be able to fulfill the assessment requirements for a particular grade” (p.1). Therefore, in line with the special needs White Papers of 1995 and 2001, schools are given the “flexibility to adapt programs to meet the needs of special needs learners, so that some assessment decisions are likely to be made at local level” (Pepper, 2007:20). Essentially, this means that schools are responsible for addressing barriers in their assessment practices and for providing Deaf and H/H learners with equal opportunities to demonstrate their knowledge and skills. However, this is seen as a time-consuming burden for many teachers. Firstly, they need to identify which barriers each learner experience. Secondly, they need to become familiar with the different types of assessment accommodations and alternate assessments and which ones to use for each particular student. Thirdly, they need to find the time in their schedules to administer these concessions. Finally, each student needs an Individualized Education Program (IEP) which consists of all the information regarding the particular learner, i.e. academic level, psychometric test results, accommodation or alternate assessment that the student needs, etc. These IEPs need to be updated and adjusted on a regular basis by the IEP team (Qi & Mitchell, 2007).

Currently, the only assessment accommodation or alternate assessment used in schools for the Deaf in South Africa is: more time and translating assessment questions into sign language. These two assessment accommodations do not provide Deaf and H/H learners a fair chance “by removing the construct-irrelevant variance created by their disabilities” (Case, 2005:7). Therefore, this research paper examined the use of online mathematics assessment as an assessment accommodation or alternate assessment for Deaf and H/H learners, one which might level the playing field by possibly removing obstacles that hinder Deaf and H/H students from demonstrating their acquired knowledge and skills.

In line with CAPS (2011), the NPA (2011) and the National Policy Pertaining to Progression and Promotion (NPPP) (2011) (DoE, 2011), teachers are advised to adapt their assessment practices for all learners to demonstrate their knowledge and skills. Therefore, all South African schools are expected to identify students who are in need of assessment accommodation and alternate

assessment to create space to accommodate these learners. These assessment accommodations and alternate assessments can include:

- Provision of the exam ‘paper’ in alternative formats (on audio tape, in large print or Braille, computer),
- Provision of an amanuensis/scribe,
- Supply of assistive devices, special equipment, etc. (Pepper, 2007:56).

Similarly, the International Review of Curriculum and Assessment Frameworks Archive (INCA) recommended the use of different forms of alternate assessment strategies. Table 1.1 below highlights these types of alternative assessments for learners with the various disabilities.

	Visual Barriers	Deafness Hard of Hearing	Deaf- Blindness	Physical Barriers	Learning Disability
Tape-Aid	✓			✓	✓
Braille	✓		✓		
Enlarged Print	✓			✓	
Dictaphone	✓			✓	✓
Video		✓			✓
Sign Language Interpreter		✓	✓		
Computer / Typewriter	✓	✓	✓	✓	✓
Alternative Questions/Tasks	✓	✓	✓	✓	✓
Additional Time	✓	✓	✓	✓	✓
Amanuensis (scribe)	✓	✓	✓	✓	✓
Oral to teacher	✓	✓	✓	✓	✓

Table 1.1: Alternate assessments recommended by the INCA

From Table 1.1 it can be deduced that alternative assessment strategies specific for Deaf and H/H learners can include: video, Sign Language interpreter, a computer, alternative questions, additional time, amanuensis and orally/ signing. However, this isn't what is happening in classes for the Deaf and H/H learners. They are still taught in the traditional way of chalk and talk, which result in all kinds of difficulties for Deaf and H/H students (Pagliaro, 2006).

In line with the INCA's recommendations, the WCED released a circular: 0017/2016 which provides recommendations for administering alternate assessment or assessment accommodations for schools for Deaf and H/H learners. Table 1.2 provides detailed examples of these recommendations.

	Visual impairment/ Color blindness	Deaf/ Hard of Hearing/ Deaf/ blind	Physical barriers	Learning difficulties	Behaviour, Anxiety, ADD/ ADHD/ Autism/Psychosocial disorders	Limited functional speech	Other medical conditions
Adaptation of questions							
Additional time							
Digital player/recorder							
Braille							

Computer/v oice to text/ Text to voice							
Enlarged print							
Handwriting							
Medication/ food intake							
Oral examination							
Personal assistant							
Prompter							
Reader							
Rest breaks							
Scribe							
Separate venue							
Sign Language Interpreter							
Spelling							
Transcriptio n of Braille							
Video/DVD recorder/We bcam							

Table 1.2: Suggested assessment accommodation for learners with disabilities [Adopted: WCED Circular: 0017/2016]

As seen from Table 1.2 one can observe that assessment accommodation or alternate assessment for Deaf and H/H learners can make use of various modifications. These can include adaptations of questions, additional time, a computer, oral examination, a reader, a scribe, rest breaks, Sign Language, separate venues, spelling and a video/DVD recorder/ Webcam.

The next section includes a description of the effects hearing impairment have on mathematics teaching and learning.

1.1.2 The effects of hearing impairment on mathematics education

Research findings on mathematics performance indicate that there exist delays of about three years between Deaf and Hard of Hearing Learners and their hearing peers (Nunes & Moreno, 1998; Traxler, 2000; Nunes & Moreno, 2002; Zarfaty, Nunes & Bryant, 2004; Bull, Marschark & Blatto-Vallee, 2005). These delays include additive reasoning and time differentiation (Nunes & Moreno, 2002), difficulty interpreting mathematics word problems (Kelly, Lang & Pagliaro, 2003; Pagliaro & Ansell, 2002), poor arithmetic abilities (Frostad, 1999; Nunes & Moreno, 1998), working with fractions and slower reaction rate (Bull et al. 2005:224).

Nunes and Moreno (1998) posit that hearing loss does not contribute to the poor performance of Deaf and H/H learners in school mathematics. However, this doesn't mean that their hearing loss has no influence on their learning. According to Pagliaro (2006), factors that do contribute to Deaf and H/H learners' poor performance in school mathematics are language, informal learning and the type of instruction. For example, Deaf and H/H students experience difficulties with language which has a direct influence on their mathematics performance. This view is in line with different researchers (Barham & Bishop, 1991; Kelly & Mousely, 1999; Kidd & Lamb, 1993; Kidd, Madsen, & Lamb, 1993) who posit that language difficulties further influences reading and comprehension of mathematics questions. Essentially, this means that Deaf and H/H learners find it difficult to interpret mathematics questions posed in Afrikaans or English since neither Afrikaans nor English is their home language. Looking at the sentence structure issue, it means that because the structure of Afrikaans/English to that of Sign Language differ, Deaf learners find it difficult to follow Afrikaans/ English sentences. On the other hand, since the

structure of Afrikaans mathematics questions and Sign Language, mathematics questions differ in grammatical structure, it further poses threats to Deaf and H/H learner's performance in mathematics. Moreover, Sign Language is not an official language. Therefore a database of mathematics vocabulary is nonexistent, and hence teachers find it difficult to translate the actual meaning of mathematics questions. Further discussions on these debates will follow in chapter 2.

The next section includes mathematics assessment set out in the Curriculum and Assessment Policy Statement (DBE, 2011) which underpins the evaluation framework for mathematics in the different school phases.

1.1.3 Mathematics assessment set out by CAPS

CAPS regulates the Mathematics assessment for all learners irrespective of their disability (DBE, 2011). The purpose of evaluation is twofold i.e. Formative and Summative. Formative assessment also referred to as assessment for learning is an inherent part of the teaching and learning process. The administration of Summative assessment usually occurs after a topic or a range of related topics in mathematics. The results of summative assessments are recorded and used for progression and promotion purposes. Moreover, two types of summative assessments are prescribed by CAPS (DBE, 2011) i.e. Formal evaluation and Informal assessment. Firstly, the Informal assessment also referred to as assessment for learning is used to collect continuous data from learners to adjust the instructional practices of teachers and to meet the needs of students. Secondly, the formal assessment also referred to as assessment of learning includes School-Based Assessment (SBA) i.e. tests, assignments, projects, investigations and examination together with the end of the year exam.

The SBA accounts for 40 % of the learners' year mark, while the final exam accounts for 60 % of their year mark (NPPP, 2011). Furthermore, SBAs are administered in the mathematics classroom and supervised by the mathematics teacher. The SBAs occur through the use of assessment accommodation, specifically translating each question into sign language. The problem arises when Deaf and H/H learners need to engage in the written exams. Deaf and H/H

students perform poorly in these written exams which result in failing mathematics and repeating the grade.

Deaf and H/H students perform poorly in writing exams due to the following reasons. Firstly, they are taking exams under the same conditions as their hearing peers, which means, they must do a pencil and paper exam. Accordingly, taking tests under such conditions becomes problematic due to language, reading and interpretation problems (Pagliaro, 2006; Kelly, Lang, and Pagliaro, 2003, Frostad, 1999 & Nunes and Moreno, 1998). Although the paper tests include examples, it's the same written examples that present obstacles. Secondly, teachers on exam duty cannot assist Deaf and H/H learners with adequate signs when asked to define mathematics terms in proper Sign Language, which causes pupils leaving those questions blank.

Essentially, this means that paper exams, without any assistance from the mathematics teacher, are inaccessible for Deaf and H/H students, hence do not give them a fair chance to answer these type of assessments. Accordingly, valid inferences cannot be drawn from marks obtained in these type of evaluations. The South African Qualifications Authority Act (SAQA), no. 58 of 1995 explicitly guarantees the credibility of assessments through the principle of fairness. This principle emphasizes that all assessments should not be in any instance, advantage or disadvantage any learner. Along the same line, the Education White Paper 6 on Special Needs Education: Building an Inclusive Education and Training System (2001), which underpins legislation and policy regarding learners who experience barriers to learning, overemphasize the support learners with barriers must receive in relation to the support they need. So, although state policies guarantee accessible assessments for all students irrespective of their disability, the administration at school level is in need of revision.

The next section provides an account of the rationale for computer-based assessment in the case of Deaf and H/H learners.

1.1.4 The rationale for computer-based assessment specifically for Deaf and H/H learners

Computer-based assessments have proven to create opportunities for students with learning disabilities to obtain better marks in school subjects (Babbitt & Miller, 1996; Kumar & Wilson, 1997; Ryba, Selby & Nolan, 1995; Singleton, 2004; Woodward & Rieth, 1997). Similarly, Bottge and Rueda (2006) developed a multimedia mathematics, computer-based assessment (CBA) and compared it to a paper and pencil assessment (PPA). Not only did they find that CBAs provided learners with access to more information on mathematics problems without having to recall the information from past lessons, but it also eliminated the cognitive demand students with learning difficulties experience. Kumar and Wilson (1997) support this argument and posit that the use of ICTs to administer PPAs can reduce these cognitive demands. The possibility of CBAs to reduce the cognitive demand of low-performing learners presents a venue for research on how the use of CBAs can assist Deaf and H/H students.

Peltenburg, Van Den Heuvel-Panhuizen, and Doig (2009); the Malaysia Examination Board, Ministry of Education (2004); Woodward & Rieth (1997) and Damon (2015) also provide evidence of the positive impact CBAs have on the performance of Deaf and H/H learners. These arguments will be elaborated on in chapter 3.

Methodologically the current study makes use of WIRIS, a plugin in Moodle. “WIRIS is a powerful calculator with a friendly math editor, and it allows for the creation of random self-evaluation exercises for students after using the learning units in Moodle” (Mora, Merida & Eixarch, 2011:752). Essentially, this means that WIRIS can represent mathematical expressions and through the use of the WIRIS Computer Algebra System (CAS) it can also represent integers, decimals, rational, irrational and complex numbers (<http://www.wiris.com>). A CAS is a specific mathematics software that reduces the cognitive load of users. In other words, it computes algebraic tasks which reduce the cognitive demand of users by manipulating mathematical equations symbolically, in contrast to a regular calculator which handles calculations numerically (Davenport, Siret & Tournier, E., 1988). A discussion about the rationale for using WIRIS follows in chapter 4.

From the above research findings, the following becomes apparent:

- Paper and pencil mathematics assessments pose language, reading and interpretation problems for Deaf and H/H learners,
- Assessment accommodation and alternate assessment practices only stretch as far as using extended time, amanuenses and sign language,
- The effects of computer-based assessment on the performance of Deaf and H/H learners and,
- A lack of mediated learning experience in the case of Deaf and H/H students.

To my knowledge, limited research papers have been published about alternate assessment practices for Deaf and H/H students, especially in a South African context. Furthermore, no study could be found based on online mathematics assessment as an alternate assessment for Deaf and H/H learners in South Africa. I argue that an alternate assessment in the form of online mathematics assessments might not only give Deaf and H/H students a fair chance to answer these type of assessments, but it might increase their performance in school mathematics. Moreover, it might also provide mathematics teachers with insights into the cognitive processes of Deaf and H/H learners while doing mathematics. Essentially, the need exists to provide Deaf and H/H students with a cognitive tool to assist them with the difficulties they experience in answering paper and pencil assessments and with equal opportunities to do well in formal mathematics assessments.

1.2 Aim of the study

Currently, as mentioned earlier, there exists no research on online mathematics assessment as an assessment accommodation or alternate assessment for Deaf and H/H learners in a South African context. Although state legislation advocates the administration of these types of concessions, the “how” and “what” at school level are still problematic. Since Deaf and H/H learners require the same mathematics skills as their hearing peers, providing them with alternate forms of assessment to showcase what they have learned, is in line with policy statements and should be made available to Deaf and H/H learners.

Firstly, this research study sheds light on the use of assessment accommodation and alternate assessment around the world and focused on the influences of such assessment types on Deaf and H/H learners' performance in school mathematics. Secondly, this research study provided detailed insights into the use of online mathematics assessment as an alternate assessment strategy. In the case where these insights were positive, it can contribute to improvements in mathematics scores of Deaf and H/H learners and hence provide them a chance to gain access to further education and training as well as possible career advancements. Therefore, the aim of the current study was to provide Deaf and H/H learners with equal opportunities to engage in formal assessment, one that facilitates the cognitive demand PPA present, through the development of online mathematics assessments for Deaf and H/H learners. These types of mathematics assessments will give teachers an alternative to the traditional way of assessing Deaf and H/H students. Hence, it was necessary to understand how Deaf and H/H learners respond to these types of alternate assessments.

A further aim of this study was to inform the administration and development of alternate standardized assessments. Currently, standardized assessment referred to as the Annual National Assessments (ANA) for Grades 3, 6 and 9, are written by all learners including Deaf and H/H learners.

1.3 Statement of the problem

Deaf and H/H learners perform poorly in mathematics pencil and paper assessments due to language, reading and interpretation difficulties. Since the final exam weights, 60 % of the year mark, obtaining low scores in it, results in failing mathematics and even repeating the grade. Furthermore, online mathematics assessment might be a possible solution to current problems Deaf and H/H learners experience with PPA. Moreover, the White Paper on e-Education (DoE, 2004) advocates the use of ICTs in transforming teaching and learning. I, therefore, argue that online mathematics assessment as an alternate assessment might provide these learners with the cognitive tools to overcome difficulties paper and pencil exams present as well as enhance the accessibility to mathematics assessments.

1.4 Research Question

How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners? Secondary questions that relate to the central research question are:

- What characteristics should online mathematics assessment adhere to provide mathematics teachers with insights into the cognitive functions and dysfunctions of Deaf and H/H learners?
- How can the use of online mathematics assessment as an alternate assessment mediate the learning process of Deaf and H/H learners?
- What are the operational implications of online mathematics assessment for Deaf and H/H learners as well as for teachers?

1.5 Research Methodology

A successful study is one that is characterized by a well-constructed research design. A research design is defined as the “what, where, when, how much, by what means concerning an inquiry or a research study” (Kothari, 2004:31) and also relates to the blueprint of what the researcher intends to do on data collection and data analysis. Essentially, this research study is coined a qualitative research, specifically participatory action research (PAR). According to McIntyre (2008), PAR is a joint endeavor between the researcher and participants to examine possible solutions for their current practices. PAR is underpinned by the following aims, i.e. “(a) a collective commitment to investigate an issue or problem, (b) a desire to engage in self- and collective reflection to gain clarity on the subject under investigation, (c) a joint decision to engage in individual and/or collective action that leads to a useful solution that benefits the people involved, and (d) the building of alliances between researchers and participants in the planning, implementation, and dissemination of the research process” (2008:2). In other words, McIntyre believes that through PAR, the researcher and participants can collectively gain from the benefits of the outcome of this type of research.

The rationale for choosing this methodology was due to the negative impact PPA have on Deaf and H/H learners. This phenomenon is a major problem for the Deaf and H/H community since it not only presents them with inaccessible written assessments, but it also contributes to their poor performance in school mathematics. Poor performance in school mathematics can lead to failing mathematics, and this can further result in not gaining access to higher education which in turn limits their career opportunities. Accordingly, a collective approach, to finding solutions to this threatening issue was needed. Furthermore, action on possible solutions from all the participants involved was required. The characteristics of PAR include collaboration, empowerment, and action. Therefore, it was deemed necessary to use this methodology within the current research study.

1.5.1 Sampling

Purposeful sampling was utilized in this research study as proposed by Marshall (1996). The participants were all selected within the Senior Phase (Grade 8) at a school for the Deaf and H/H in the Western Cape. These learners were selected on the grounds of their hearing loss. These learners were asked to participate in this research study by interacting with the online mathematics assessments. Furthermore, while they were interacting with the online mathematics assessments, the teacher/researcher observed them while taking field notes. Afterward, the Grade 8 learners participated in an interview session with the teacher-researcher based on their experience with the online mathematics assessments. After the interviews were conducted, the information gathered was used to adjust the online mathematics assessments. The Grade 8 learners were given an opportunity to interact with the newly adjusted online assessments while the teacher/researcher observed them.

1.5.2 Data collection

Semi-structured interviews were used in order to examine the advantages and disadvantages of online mathematics assessment as an alternate assessment for Deaf and H/H learners. Essentially, the Grade 8 Deaf and H/H learners were asked to participate in these semi-structured interviews. The interviews were administered by an interpreter who asked the questions in Sign Language

and in return the learners provided their responses via Sign Language. The interviews were video recorded and transcribed by the teacher/researcher. Furthermore, the observation was done by the teacher-researcher as he explored, with the learners, these online mathematics assessments. Additionally, document analysis was also employed. For example, while learners were actively involved in the online mathematics assessment, the captured data in the form of logs, journals and the results of the online mathematics assessments were analyzed. The aim of the interviews, observations and document analysis were to provide a detailed account of the Deaf and H/H learners' experience with the online mathematics assessment. More details on the research methods as well as the research plan are discussed in chapter 5.

The next section describes the key concepts included in the current research study.

1.6 Key concepts

This section of the research study includes key concepts relating to the research question. These definitions exemplified the setting in which online mathematics assessment must be viewed and in which way it was used for assessment accommodation and alternate assessment.

1.6.1 Mathematics assessment

According to CAPS (2011:154) assessment encapsulate “a continuous planned process of identifying, gathering and interpreting information regarding the performance of learners, using various forms of assessment. It involves four steps: generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand and thereby assist the learner’s development in order to improve the process of learning and teaching. Assessment should be both informal and formal. In both cases, regular feedback should be provided to learners to enhance their learning experience. This will assist the learner to achieve the minimum performance level of 40% to 49% required in Mathematics for promotion purposes”. A distinction is made between different types of assessments (CAPS, 2011). These include Baseline, Diagnostic, Formative, and Summative assessment. The latter is of relevance to this research study.

1.6.2 Online mathematics assessment

Online mathematics assessment is defined as the delivery of mathematics assessment over the internet. (Sangwin, 2004). This is achieved through the use of computer algebra systems (CAS) that uses computer algebra to evaluate learners' assessment tasks. The most commonly used CAS are AIM, STACK, MAPLE, Mathematica, Macsyma, Mathcad, MATLAB, WIRIS and CABLE (Sangwin, 2004; Naismith & Sangwin, 2004). This research study made use of WIRIS, a plugin within Moodle.

1.6.3 Alternate assessment

Alternate assessments are, in essence, comprehensive modifications to the standardized test format (Cawthon, 2006). For example, changing an essay question into a multiple choice question. Essentially, it means modifying the format of the questions to “effectively change what is being measured by the assessment” (Elliott, McKeivitt & Kettler, 2002). In relation to this research study, alternate assessment focused on replacing PPA with online mathematics assessments.

1.7 Provisional Chaptering

Chapter 1

This chapter includes an overview of the entire dissertation. Accordingly, this chapter consists of the statement of the problem as well as the research questions that drives this research study. Moreover, the chapter includes a preliminary literature review together with the outline of all the chapters in this dissertation.

Chapter 2

This chapter includes a detailed review of the literature relating to mathematics assessment. Firstly, it includes the underlying theories of mathematics assessment for Deaf and H/H learners. Secondly, it presents a detailed account of assessment accommodation and alternate assessment currently in use at schools for the Deaf around the world and state policies regarding assessment accommodation and alternate assessment for Deaf and H/H learners.

Chapter 3

This chapter presents the learning theory underpinned by the current research study as well as the rationale for choosing the specific learning theory. Firstly, it provides a detailed account of how Deaf and H/H learners learn in general as well as how they learn mathematics. Secondly, it provides an account of Mediated Learning Experience as the underlying theory of the current research study. Thirdly, it illuminates the role of computers in MLE as well as the role online assessment can play in exposing Deaf and H/H learners' thinking processes on mathematics learning.

Chapter 4

This chapter includes online assessment, especially literature relating to online mathematics assessment unique to Deaf and H/H learners as well as research on issues of validity and reliability of online mathematics assessment. Secondly, it highlights, theories relating to online mathematics assessment for Deaf and H/H learners. It also includes the use of WIRIS as a plugin in Moodle and the use of WIRIS CAS and quizzes to develop online mathematics assessments for Deaf and H/H learners.

Chapter 5

This chapter outlines the research design and methodology employed in the current research study namely, PAR. It also highlights the rationale for choosing this method as well as the data gathering tools that will be used, i.e. semi-structured interviews, observation and document analysis. The chapter concludes with the data analysis techniques utilized in the current research study as well the limitations of the current study.

Chapter 6

This chapter provides a detailed analysis of the findings of the research study by illuminating the researcher, as well as the participants' interactions with the online mathematics assessments. It also provides a detailed description of the main categories identified by the researcher as well as how the online mathematics assessments were adjusted based on the reflection phases.

Chapter 7

This chapter concludes with possible answers to the research questions. It also highlights recommendations which were exposed by the current research study as well as recommendations for further research studies.

1.8 Ethical considerations

1.8.1 Ethical clearance

Firstly, since the participants in this research study are all minors, ethical approval was obtained from their parents. Also, an assent form was completed by each Deaf and H/H learner. Secondly, the WCED was contacted for permission to embark on this research study. Thirdly, permission from the governing body of the school where the study took place was acquired. Finally,

permission was obtained from the ethics committee of Stellenbosch University.

1.8.2 Confidentiality

Any information gathered in this study, which might identify all participants, remained confidential and were disclosed only with the members' permission or as required by law. Information obtained from this study was kept confidential through the use of coding procedures as well as the safeguarding of data.

- **Coding Procedure**

The ethical integrity of this study was maintained by conducting this investigation under the auspices of the ethics committee of Stellenbosch University. Moreover, the privacy, anonymity, and confidentiality of the Senior Phase learners' records were secured in my research report by replacing their real identities with pseudonyms. The researcher coded the data using the aliases, especially in the case of publication. Furthermore, the researcher instituted the maximum effort and exercise caution to protect the identity of the learners. The Senior Phase learners thus remained anonymous.

- **Plans to safeguard the data**

The biographical data, as well as the transcribed interviews of the learners, was kept safe on the researcher personal computer's hard drive. No one except the researcher had access to his personal computer which was password protected.

- **Results**

The results will be made available to the following role players: my supervisor, Stellenbosch University, principal of our school and the WCED. A summary of the research findings will be made available to all the participants. It will also be posted on SunScholar.

1.9 Potential risks and discomforts

A possible discomfort might be that learners aren't too comfortable in front of the computer, and some might even suffer from computer anxiety (Panagiotakopoulos & Koustourakis, 2001). In other words, learners might experience anxiety when placed in front of a computer or are asked to use the computer in teaching and learning. However, these tensions were reduced by presenting learners with computer knowledge. From my experience with Deaf and H/H students, I have found that they lack computer knowledge, i.e. the know-how on how to operate a computer, the use of computer software as well as engaging in web-based courses can provide some kind of anxiety in learners. This approach was also in line with Chien's (2008) discovery on how to reduce computer anxiety in learners. The researcher found that by providing students with enough experience and knowledge could reduce their computer anxiety. For this reason, my approach was to present students with enough computer experience through games and simulations to familiarize themselves with computers and computer environments. Also, since I am teaching computer practice for Grades 4 – 9, I have already implemented such approach.

In the instance of mitigating the power relationship between the teacher-researcher and the learners, the following method was used. Since this research study was underpinned by constructivism as well as mediated learning experience, the teacher-researcher wasn't seen as the sole knowledge provider. He only created opportunities for learners to construct their knowledge. Essentially, the teacher-researcher did not misuse his power but provided students with high-quality learning materials for them to become responsible for their learning experience and hence become autonomous learners. Moreover, during the semi-structured interviews suggestions were taken from pupils to make adjustments to the learning materials. Accordingly, the teacher-researcher was sharing power with students by using their responses to adjust the online assessments. Valuing their inputs and making adjustments to the online mathematics assessments gave them the idea that the teacher-researcher respected their opinions and that their voices counted, which in turn further strengthened the teacher-learner relationship and established a productive learning environment (Khullar & Tyagi, 2014).

Similarly, the fact that each Grade 8 learner had a choice to participate in this research study further strengthened the shared power between teacher-researcher and student. In other words, the mere fact that students could refuse to participate or withdrew from the study at any time provided them with a right to choose. Essentially, the power was in their hands to either partake or refuse to participate in this research study. Additionally, it also presupposed that the teacher did not use his power to force them into taking part in the research study just because he said so.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The research question that guides this research study is:

How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H learners?

The current chapter describes literature associated with mathematics assessment with particular reference to Deaf and H/H students. Firstly, it provides a detailed background of mathematics assessment for Grade 7 – 9, prescribed by the CAPS (DBE, 2011). Secondly, it provides a detailed account of the function concept as specified by CAPS (2011). Furthermore, it presents a description of assessment accommodation and alternate assessment and how it is being implemented in schools for the Deaf and H/H around the world with particular reference to South Africa. Thirdly, it describes alternate assessment prescribed by the NPA, for learners with disabilities. The chapter concludes with gaps of modern accommodation and alternate assessment strategies employed by schools for the Deaf and H/H and a recommendation for online mathematics assessment as an alternate assessment.

Through a critical analysis of my research problem and research questions, I have identified key concepts. These concepts provided me with a parameter within which to conduct the literature review. The aim of the literature review was to establish what has been done related to the current research topic and critically evaluating where the limitations within these documents are. Such restrictions might include problems with the research design, data collection methods or data analysis techniques which might also provide useful information on how to conduct the current research project (Johnson & Christensen, 2000).

2.2. Background

Mathematics assessment has many intentions. Firstly, it is about gathering information regarding the performance of learners. Secondly, it can provide information on the performance of pupils with the aim of implementing alternative measures. According to CAPS (DBE, 2011), mathematics assessment is characterized by four steps i.e., “generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand and thereby assist the learner’s development in order to improve the process of learning and teaching” (DBE, 2011:154). Similarly, the National Council of Teachers of Mathematics (NCTM, 2000) proclaims that the essential feature of mathematics formative assessment is to enhance mathematics learning. However, for mathematics assessment to improve learning, it should adhere to certain objectives and principles. The next section will shed light on this issue by discussing the purpose of evaluation as well as the principles of assessment.

2.3 The purpose of assessment

The DBE (2011) provides a comprehensive description of what constitutes for the purpose of evaluation. Firstly, an assessment should be used to inform teachers on their instructional practices to plan and modify these practices to comply with learners’ needs. Secondly, the assessment also informs the teacher of the success or shortcomings of their teaching and learning. Thirdly, assessments must aim at identifying learners’ strengths and needs as well as provide information on their achievements against set standards for promotion and progression purposes (DBE, 2011).

Rose, Barkmeier, Landrud, Klansek-Kyllo, McAnally, Larson and Hoekstra (2008) argue that the aim of the assessment should be: 1) to establish the placement of Deaf and H/H learners; 2) to observe Deaf and H/H learners’ progress in specific to individual learners and students as a group; 3) also for accountability purposes. The DBE (2014) agrees with this view and highlights that assessment is a means of providing teachers with useful information regarding Deaf and H/H learners’ progress within a particular phase, grade, and a specific subject. On the other hand, Rose et al. (2008) further assert that the purpose of assessment is also to determine whether curriculum objectives have been met as well as whether the Deaf and H/H learners acquired the

expected curriculum knowledge. Although this research study agrees with these views it maintains that the purpose of assessment should also include access to curriculum knowledge and skills as well as equity and redress as set out in the Government Gazette 24 June 1998, volume 396 no. 18998 (DoE, 1998).

Mostly the views above illustrate that mathematics assessment is a continual process, and the results of the evaluation can be used to determine whether learners pass or fail. Moreover, it presents teachers with a detailed account of the students' cognitive processes. Additionally, it provides teachers with insights on the success of teaching strategies and students' preference of learning styles. For mathematics assessments to adhere to these characteristics, it should be underpinned by specific principles. The next section describes these principles.

2.4 The principles of assessment

The Policy on Screening, Identification and Support (SIAS) (DBE, 2014:9) outlines the principles that are conducive to effective assessment strategies. The intent of this policy document is to enable the supervision of the educational process for learners with learning barriers. These principles include:

- “Teachers, parents and students need to be centrally involved in the process.
- Assessment needs to be multi-dimensional or systemic in nature, located within the framework of barriers experienced by the individual (learner and teacher), curriculum, school, family, community and social context levels.
- Assessment needs to be varied, including various forms and drawing from multiple perspectives.
- Standardized tests, provided they are culturally fair, can be used as part of the range of strategies employed in the assessment process with the aim of informing the teaching and learning on the nature and level of educational support that needs to be provided to the learner as part of the Individual Support Plan.
- Any request from a School-based Support Team to the District-based Support Team for specialist assessment (e.g. Medical, social, psychological and therapeutic – occupational

therapy, speech therapy, and physiotherapy) must stipulate the nature of the evaluation query and motivation for such an evaluation.

- Assessment procedures need to be guided by the principle of respect for all concerned.
- The purpose of the assessment should be transparent and open.
- Assessment needs to be appropriate and relevant to the realities and context of the person or school concerned.
- The assessment must be fair, bias-free and sensitive to gender, race, cultural background and ability.
- Assessment needs to identify BTL, with the purpose of improving the teaching and learning process.
- Assessment needs to be a continuous process.
- The different levels of the system that are involved in the evaluation process (e.g. School-based Support Teams and District-based Support Teams) need to work closely together, ensuring that assessment processes are smoothly pursued.
- The assessment must be manageable and time-efficient.
- The results of the evaluation must be clearly, accurately and timeously documented and communicated to those affected” (DBE, 2014:9).

Similarly, the Guidelines for Responding to Learner Diversity in the Classroom also provides a set of guidelines for administering tests in a classroom for learners with different learning needs which include:

- “We should have high expectations for all students.
- Every learner should have access to the standard of assessment best suited to his needs.
- The assessment strategy will disadvantage no learner.
- Teachers are accountable for children’s achievement.
- Assessment informs us about what the child can do at a particular stage.
- Assessment informs us about what support a learner needs to progress to another level.
- Every child can show what knowledge and skills he or she has learned in creative ways.
- Assessment should be authentic and make provision for multiple abilities, learning styles and levels.

- Assessment is supportive teaching practices.
- Assessment should be integrated into the education process.
- All learners can be accommodated within the flexible framework of the NCS.
- The student's abilities determine what will be expected from him/her" (DoE, 2011:12; DBE, 2011:21).

As seen from the guidelines mentioned above, it has some methodological implications, particularly when planning and administering of classroom assessment are concerned. This point will be further elaborated on in Chapter 5.

Not only does CAPS (DBE, 2011) propose these guidelines, but the NPA (DBE, 2011) also recommends the procedures to follow for assessments to adhere to all learners' needs. These methods include:

- "Design assessment tasks which would allow for different learning styles or intelligence
- Allow for group assessment tasks.
- Pace or scaffold the assessment activities
- Allow for tests and assignments to be taken orally as well as in written form
- Give multiple-choice options
- Provide tasks which require short answers for particular learners
- Allow students extra time to complete the task
- Use technology, aids or other special arrangements to undertake assessment tasks
- Keep a record of materials and evaluation tasks used
- Keep teacher's observation books for particular learners who need additional support
- Focus only on the central concepts for learners
- Focus on the positive aspects or talents of the students.
- Vary assessment activities.
- Exclude some marks collected early in the semester for a learner who performed poorly at the beginning of the year but subsequently made satisfactory progress" (DBE, 2011:14).

As seen from the above principles and guidelines, assessment for learners with disabilities should comply with the students' needs. Furthermore, assessments should be accessible to all students, and hence different strategies/methods should be used to "level the playing field" and provide learners with learning barriers the opportunity to demonstrate what they have learned. However, these methods and strategies should comply with certain criteria as will be discussed below.

Vanderyar and Killen (2003) provide such guidelines listed below.

2.5 Guidelines pertaining excellent assessment practices

Good assessment practices guarantee that reasonable deductions can be drawn from the outcomes of the assessment. It is thus crucial that assessment practices should adhere to fundamental principles. Vandeyar and Killen (2003:121) provides a framework for "high-quality assessment practices" which include "reliability, fairness, validity, discrimination and meaningful and contributing to learning". Each of these principles will be discussed below.

2.5.1 Reliability

"An assessment task can be considered reliable when the task, the conditions under which it is administered, and the marking are designed to minimize errors of judgment concerning learners' performance" (Vandeyar & Killen, 2003:120). Ultimately, they are saying that teachers should eliminate any variables that could influence students' performance in assessment tasks. For example, administering the evaluation while pupils are either hungry, tired, under stress or when interpretation problems arise due to misunderstandings of questions.

2.5.2 Fairness

Students should not be required to answer assessment questions that are in a language they don't understand. Furthermore, a balance should exist between the total of the questions and the time allocated to answer the questions. Accordingly, "the assessment strategies must be designed to ensure equal opportunity for success, regardless of the individual learner's age, gender, physical

or other disability, culture, language, socio-economic status or geographic location” (Vandeyar & Killen, 2003:121). In other words, does the mathematics assessment provide equal opportunities for all learners to showcase their academic ability?

2.5.3 Validity

Validity implicates whether the test is congruent to what it is supposed to measure. Moreover, teachers should be advised to provide enough empirical evidence to affirm the appropriateness of the conclusions drawn from assessment results. Vandeyar and Killen conclude that “Teachers should consider whether their tests are assessing appropriate content (or outcomes), but they should also consider the unique characteristics of the learners, the circumstances under which the test was administered and, most importantly, the theoretical and empirical evidence they have for reaching any conclusions on student learning” (2003:121).

2.5.4 Discrimination

This principle highlights the importance of assessments to distinguish between learners who have mastered the content being tested and those who haven’t mastered the material being tested. Therefore, it is essential that the teacher analyzes the results and hence try to examine why some learners performed better than others.

2.5.5 Meaningfulness and contributing to learning

Assessments should, by all means, be meaningful to all students. Whether an assessment is useful will ensure pupils’ understanding of the content knowledge. Accordingly, teachers should provide students with the rationale for taking the assessments. Furthermore, teachers should associate assessment tasks with appropriate learning outcomes and ensure that assessment tasks are clear and learners understand the usefulness of the assessment task concerning their learning.

In line with Vandeyar and Killen’s (2003) guidelines for excellent assessment practices, the current administration of evaluation practices, especially those in schools for the Deaf does not

comply to some of the guidelines. Firstly, the assessments are administered under the same conditions as for hearing learners, i.e. in a written format and heavily text-based. As a result, Deaf students are expected to interpret written test items, although research has proven that written text presents a barrier for Deaf and H/H learners. Therefore, these assessments are unfair, and no valid inferences can be drawn from the test results. Secondly, the characteristics of these students expect curriculum content to be in a format they would understand and therefore be provided with a fair chance to showcase what they know. Although government policies advocate some form of adjustment of content in the shape of assessment accommodation or alternate assessment, this only stretches as far as signed responses or signed directions in some schools for the Deaf and H/H.

Before I begin my discussion about the different types of assessments prescribed by the NCS (DBE, 2011) it is deemed necessary to provide a description of norm-referenced and criterion-referenced assessments.

2.6 Norm-referenced and Criterion-referenced assessments

Criterion-referenced	Norm-referenced
<ul style="list-style-type: none"> • Learners are critically appraised. • Students are evaluated individually. • Preset criteria are being used. • Measurements include achievements in content and skills of a particular Learning Area (LA). • All the learners are rated in line with the criterion used for assessment. • The preset standard is based on a clear set of objectives in line with the quality of evaluation. 	<ul style="list-style-type: none"> • Learners are critically appraised by assessing them in line with their peers. • Learners are evaluated as a group. • Evaluations are in line with the curriculum and are standardized and include competency tests. • The mean of learners' marks is obtained and used. • Adaptations to the scores are being made to be on par with the student group.

<ul style="list-style-type: none"> Provides a detailed outline of learners' skills obtained in a Learning Area. 	
--	--

Table 2.1: Norm referenced and criterion referenced assessment: [Adapted from the principles and guidelines for assessment of NQF registered unit standards and qualifications, SAQA, 2001:25]

Concerning Deaf and H/H learners, the current research study focus on criterion-referenced assessments. Since criterion-referenced assessments can provide the teacher-researcher with information regarding Deaf and H/H students' advancements towards the objectives of each learners' Individual Education Plan (IEP). Accordingly, adjustments can be made to the teaching strategies employed by the teacher. The two criterion-referenced assessments include Formative and summative evaluations.

The next section focuses on the specific forms of assessments set forth by the NCS (DBE, 2011).

2.7 Different types of assessments

The NPA (DBE, 2011) underpins the various kinds of assessments conducive to classroom assessments in South Africa. Accordingly, it distinguishes between formal and informal assessments. For both formal (Summative) and informal (Formative) assessments, it is crucial that all learners have a clear picture of what they will be assessed on. Furthermore, students should receive immediate feedback directly after administering the test which can provide meaningful information to learners on their acquired knowledge and skills.

“Projects, oral presentations, demonstrations, performances, tests, examinations, practical demonstrations, etc.” are all types of formal assessments and should be in line with “age and developmental level of the learners in the phase” (NPA, 2011:4). For this reason, it should be well designed with clear content objectives to guarantee that different kinds of skills are being measured.

The NPA (DoE, 2011) proposes various types of assessments to render evidence of learners' academic achievements. These include Formative Assessment and Summative Assessment (CAPS, 2011). A detailed description of Formative and summative assessments will follow.

2.7.1 Formative assessment

Formative assessment which is also coined “assessment for learning” (DBE, 2011:154). This type of evaluation is integrated into the teaching and learning process (SAQA, 2001; CAPS, 2011). Not only does it focus on corroborating with teaching and learning, but it also guides teachers in contriving future teaching and learning. Furthermore, this type of assessment distinguishes between the strengths and the weaknesses of each learner (DBE, 2011). Moreover, it provides continual feedback to students about their learning processes. Accordingly, the results of these types of assessments provide the teacher with useful information on how ready they are to perform summative assessments. Although learners are not graded for these type of evaluations, the progressive nature of it acts as a stepping stone to summative assessments. Examples of formative assessments include self-assessment, peer assessment, observation assessment, portfolio assessment, performance assessment and dynamic assessment.

2.7.2 Summative assessment

Summative assessments are administered after a sub-section of a topic or at the end of a theme. It is also referred to as assessment of learning. This type of assessment is imperative since it is recorded and presented for progression purposes in the case of Grades 1 – 8 and for promotion purposes in the case of Grades 9 -12 (CAPS, 2011). Accordingly, these types of assessments provide educators with useful information regarding the competencies of learners. Additionally, it also highlights the barriers students experienced, the comparison of previous and acquired knowledge and skills as well as whether the student can advance to the next grade or not. This means, based on the results accumulated in summative assessment, students can either pass or fail mathematics. Examples of these types of mathematics assessments include tests, assignments, investigations, projects, and examinations.

Traditionally this type of assessments is pencil and paper based where learners need to input their response on paper. Santrock (2011:558) refers to this as “content and input based approach to assessment”. In other words, learners must retrieve information presented to them by either the teacher or obtained from notes or textbooks. Furthermore, he distinguishes between two types of item formats within assessments. These include selected response items and constructed response

items.

2.7.2.1 Selected-response items (SR)

SR consists of selection learners must choose from, which is provided by the teacher. For example, instead of students fabricating a response, the teacher provides a set of answers from which the student must choose (Santrock, 2011). Examples of commonly used question types include embedded solutions also known as cloze questions, true/false questions and fill in the blank answers (Coy, 2013). While true or false questions expect learners to choose whether the answer is true or false, fill in the blank questions requires learners to give the missing word or number. Multiple choice questions are a selection of possible answers the learners must choose from in order to support the statement or question, as for matching questions, learners have to choose from possible answers, the correct response that matches the problem.

2.7.2.2 Constructed-response items (CR)

The most commonly used CR items are short-answer and essay items. On the one hand in a short-answer question, the learners are required to write short answers in response to the questions. On the contrary, in an essay type question, the pupils are required to write an essay or a paragraph to respond to the question. These types of responses do not allow students to choose from a list of answers, they have retrieved the knowledge from their own “archives” in order to respond to the question. The current research study makes use of SR and CR items.

The next section includes a description of school-based assessment and how it is being implemented at the school level.

2.8 School-based Assessment

Assessment prescribed by CAPS (2011) includes School-Based Assessment (SBA), Practical Assessment (PA for Further Education and Training Phase) and the examination at the end of the year (NPA, 2011). These assessments are intended “to address the content competencies, skills,

values and attitudes of the subject, and to provide learners, parents, and teachers with results that are a meaningful indication of what the students know, understand and can do at the time of the assessment” (NPA, 2011:6). Essentially, this means that the SBA and PA are administered throughout the year to assess learners on their competencies and skills. On the other hand, the rationale for the final examination is to “provide reliable, valid and fair measures of the achievements of learners in the subjects offered from Grade 4 onwards” (NPA, 2011:6).

SBA is mandatory for progression and promotion purposes. Table 2 below illustrates the weighting of SBA within the various school phases.

Phases	School Based Assessment components	Final Examination
Foundation Phase (FP)	100	0
Intermediate Phase (IP)	75	25
Senior Phase (SP)	40	60
Further Education and Training Phase (FET)	25	75

Table 2.2: The weighting of the SBA and End of the year exam prescribed by CAPS (DBE, 2011)

Since this research study only focuses on learners in the Senior Phase, the weighting for SBA is 40% and 60% for the final examination written in December.

The figure below summarizes the different types and forms of assessment prescribed by the DoE.

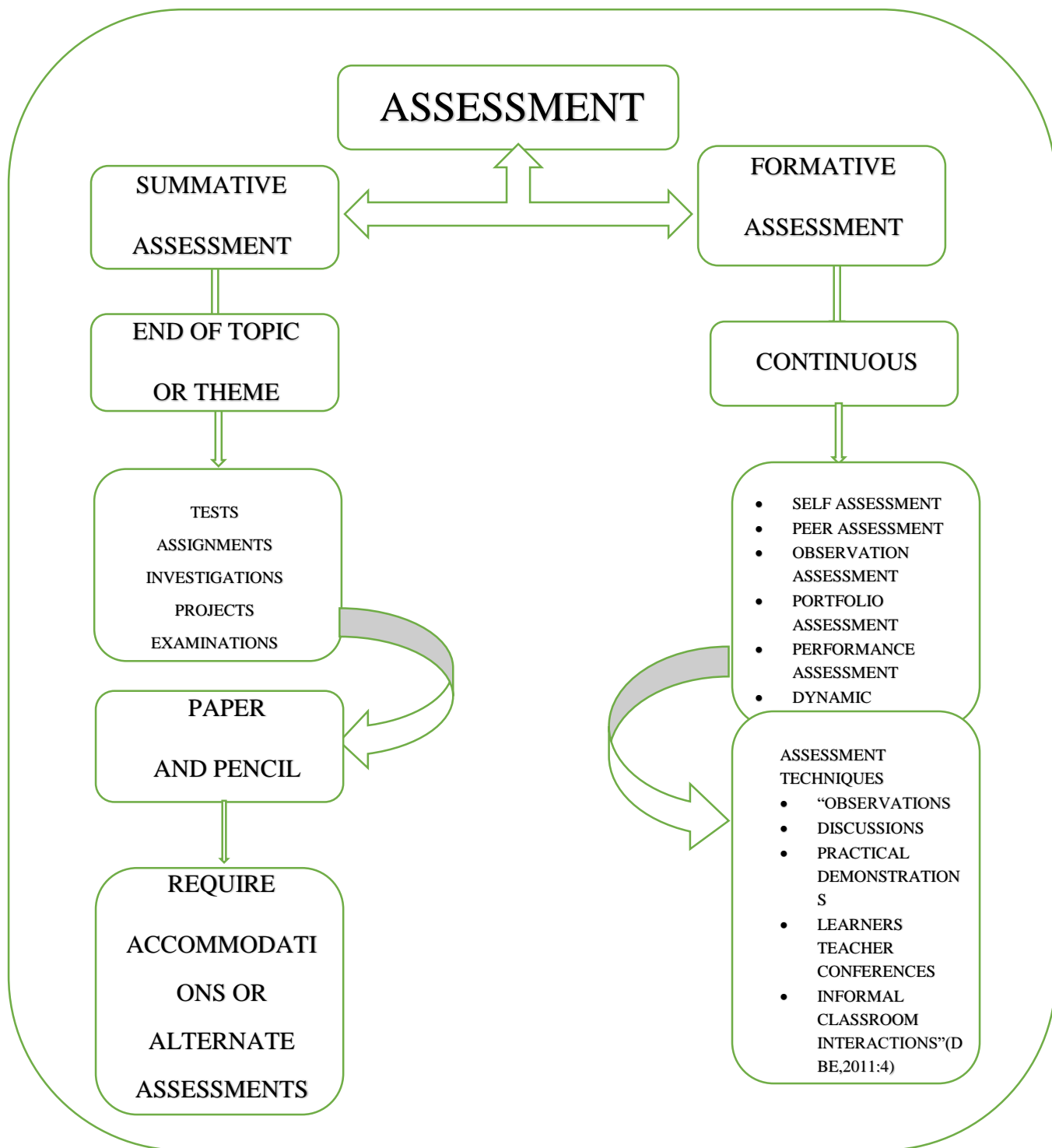


Figure 2.1: Different types and techniques of assessment set out by the NCS (DBE, 2011)

2.8.1 The Assessment content presented by CAPS

CAPS provides teachers in South African schools with a framework for teaching and learning (DBE, 2011). Therefore, CAPS prescribes what should be taught and how it should be assessed. Accordingly, the Mathematics Curriculum and Policy Statement Grades R-12 provides mathematics teachers in all phases with guidelines for implementing the mathematics curriculum as well as assessment practices (DBE, 2011).

As prescribed by CAPS (2011), mathematics in all phase includes five content areas which include:

- “Number, Operations, and Relationships
- Patterns, Functions, and Algebra
- Space and Shape
- Measurement and
- Data handling” (CAPS, 2011:11).

Each of these content areas should be administered throughout the school year and assessed accordingly. Since this research study utilizes assessment activities based on functions, only this content area will be discussed in detail.

2.8.2 Mathematical Functions

Mathematical functions are crucial in our everyday lives (O'Callaghan, 1998; Kalchman and Koedinger, 2005). For example, we use functional relationships when we buy vegetables or fruit per kg or pay for petrol per liter. Moreover, functions are even used in statistics in cricket and baseball matches. However, learners aren't acutely aware of each functional relationship, especially in the case of Deaf and H/H learners where incidental learning is problematic. For example, Deaf students don't hear or understand that fruit, meat or vegetables are sold per kilogram. They know the sign for it, but they find it difficult to grasp that if I pay R4, 00 for 2kg apples, the functional relationship can be applied to more bags of apples, etc. On the other hand, representing these functional relationships and also moving between the representations also presents problems. My point here is, while hearing learners hear or experience these concepts at

home (buy 1kg of meat or a price drop in petrol i.e. R13, 20 for 1liter of petrol) or even at the shop or while playing with their friends. In other words, they learn these concepts incidentally, which provide them with some basic understanding when they enter school (Pagliaro, 2006). Deaf learners, on the other hand, are excluded from this experience and usually become familiar with these concepts in a formal teaching environment.

Although Deaf and H/H learners struggle with all aspects of mathematics learning, they find it tough to grasp mathematical functions. This has become apparent from my experience as a mathematics teacher for the Deaf and H/H. Kalchman and Koedinger (2005) is also of the view that all learners experience difficulties with mathematical functions, especially concepts such as variable, continuous, discrete as well as interpreting graphs, tables or function formula.

DeMarios and Tall (1999) affirms that mathematical functions “has become a central concept within schools and university curricula around the world” and that it can be utilized as a “powerful foundation for logical organization” (p.257). Dubinsky (1993) shares this view and asserts that “functions form the single most important idea in all of the mathematics, at least regarding understanding the subject as well as for using it” (p. 527). On the other hand, Knuth (2000) argues that “the introduction of algebraic and graphical representations of functions can be seen as a crucial moment in mathematics learning” (p.48). Although the concept of function is seen as a vital part of the school mathematics curriculum, it is still a complex topic for all learners.

Verhage, Adendorff, Cooper, Engel, Kasana, le Roux, Smith and Williams (2000) agree with the view that students struggle with the concept of function and assert that the complexity of functions become a major stumbling block for learners in the Grade R-12 phase. Although Willoughby (1997) agrees with this argument, he still maintains that mathematical functions are an essential component of the school mathematics curriculum and that realizing or understanding it will increase learners’ chances of success in other topics in mathematics. Mann (2004) agrees with this view and asserts that the concept of function is “essential for success in calculus, differential equations and beyond” (p.1). On the other hand, Willoughby (1997) claims that the reason why learners struggle with mathematical functions is due to the abstract manner in which the topic is being taught at school level. Therefore, teaching the function concept in such a way

may be a result of teachers lacking the necessary skills to transmit this type of knowledge, or they have not attained the knowledge regarding mathematical functions (Willoughby, 1997).

O'Callaghan (1998) proposed a functional model which is connected to a set of problem-solving skills and made up of “four components of competencies” such as “modeling, interpreting, translating and reifying” (p.1). Modeling denotes representing real world problems by making use of a set of mathematical tools i.e. mathematical functions. Modeling is accomplished by representing a mathematics problem through symbols, using tables, graphically, verbally or in a written format. Interpreting, however, include making judgments of the different representations of mathematics problems using learners’ subjective interpretation of it (O’Callaghan, 1998). Translating refers to the ability of students to move between the various representations of a function. In other words, from an input-output machine to tabular data, or from an equation or expression to a graphical representation.

DeMarios and Tall’s (1999) studied mathematical functions which include the function notation, the function machine (input-output box), symbolic (algebraic formulae), numeric (table format) and geometric (graphical format) as well as the written and verbal/sign form, as facets of the function concept. They also propose the facets and layers of the function concept mentioned above which the current study utilizes. Figure 2.2 provides an illustration of these facets and layers.

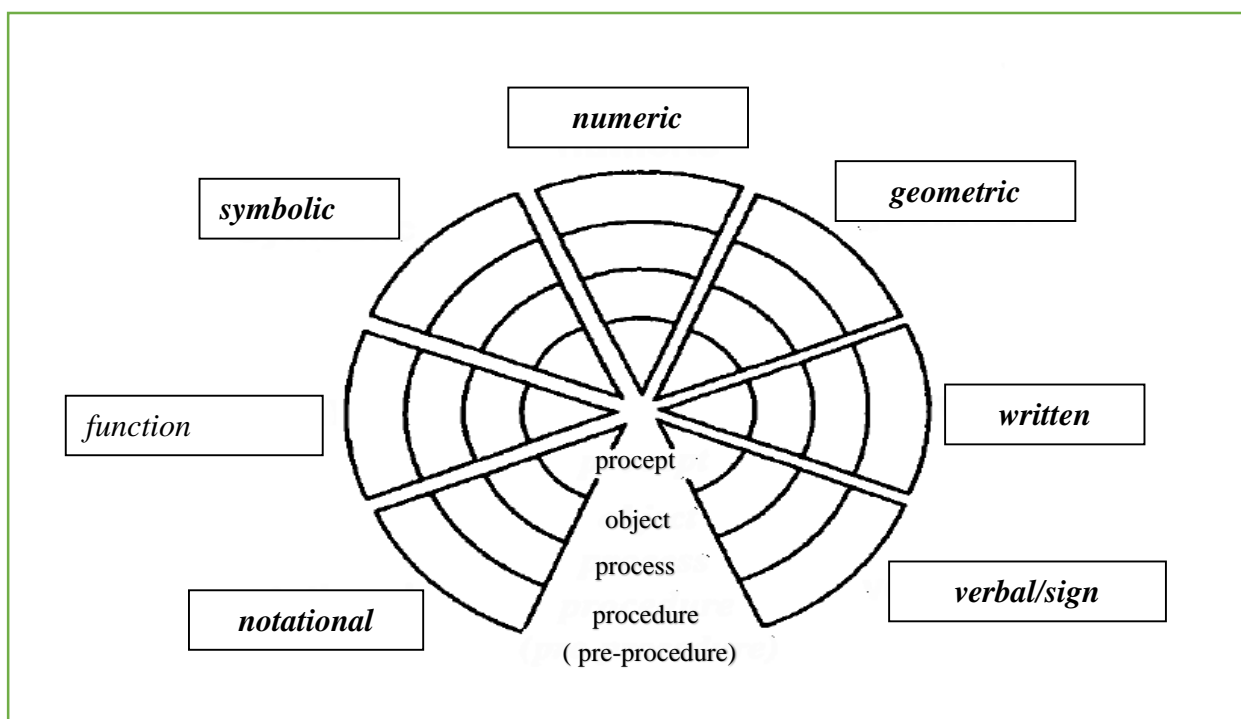


Figure 2.2: An example of the facets and layers of mathematical functions (Adapted from DeMarios & Tall, 1999:687)

The function concept is depicted as a disc consisting of different facets and layers. DeMarios and Tall (1996) explain that facets of the function concept should be interpreted as diverse modes of “thinking about it and communicating to others, including verbal (spoken), written, kinesthetic (enactive), colloquial (informal or idiomatic), notational conventions, numeric, symbolic and geometric (visual) aspects” (p.297). Also, they assert that layers denote different degrees of the “depth dimension in the development via the cognitive process to mental object” (DeMarios and Tall, 1996:298).

Learners engaging with the function concept start off with pre-existing knowledge of mathematical functions, although they aren’t aware of it. It is also an indication that the learners have not reached the procedure layer yet. Students operating within the procedure layer is a sign that they rely strictly on step-by-step activities. For them, comprehending mathematical functions are nothing else than a linear process of following steps or actions in a sequential manner.

On the other hand, learners operating in the process layer accept that there exists a process between the input and output values, although they ignore or isn't dependent on following the step-by-step actions as in the procedure layer. The object layer includes learners that can “treat an idea as a manipulable mental object to which a process can be applied” (DeMarios & Tall, 1999:687), whereas learners operating within the *procept* layer can move between mental object layer and the process layer quickly. Gray and Tall (1991) claim that the *procept* layer is the blending of a process (seven plus five), a concept as a result of that process (the sum) and a symbolic representation that elicit either the concept or the process ($7 + 5$). In other words, one particular notation can be used to symbolize both a process and a product of the same process, i.e. $7 / 5$, which is a process (counting: one, two, three, four, five, six, seven), a concept (numbers) and a concept (addition).

Although the disc is depicted as a whole, it should be viewed as slices that are linked together in any way and thus indicating how it is either absent or one-directional for particular learners. This disc model will be utilized to gain insight into Deaf and H/H students' understanding of the function concept, at which facet and layer they are and how their understanding changed while they engaged within the online mathematics assessments.

In summary, from the perspective of Mathematics Education as a discipline, mathematical functions are a crucial part of the mathematics curriculum and should be taught in a realistic manner focusing on all the multi-representational features of it.

2.8.3 The function concept as prescribed by CAPS

Within the mathematics curriculum for the Senior Phase (Grades 7 – 9), there are currently five content areas i.e. “Numbers, Operations, and Relationships; Pattern, Functions, and Algebra; Space and Shape; Measurement and Data Handling” (CAPS, 2011:11). Each of these content areas has specific content focuses. The content focus of dealt with in this research study includes “description of patterns and relationships through the use of symbolic expressions, graphs and table; and identification and analysis of regularities and change in patterns and relationships that enable learners to make predictions and solve problems” (CAPS, 2011:10). The particular content focus of the function concept includes: Therefore, the objective of including the concept

of function in the CAPS curriculum is to provide learners with the concepts and skills that focus on manipulative skills in algebra. For this reason, each phase is a build up to the next and also the building blocks for the next stage.

Within the Foundation Phase mathematics curriculum (Grade 1-3), mathematical functions include developing competencies in number and geometric patterns. In other words, learners within this phase should be able to describe patterns and relationships by utilizing symbolic expressions, graphical representations and tabular data (CAPS, 2011). Learners should also be able to identify and examine commonalities and differences between patterns and relationships for them to solve such problems. Moreover, the weighting for Patterns, Functions, and Algebra within this phase is “10 % (Grade 1), 10% (Grade 2) and 10% (Grade 3) as for the time allocation per annum estimated at 8 hours” (CAPS, 2011:11).

The Intermediate Phase Mathematics Curriculum (Grades 4-6) prescribes the teaching and learning of mathematical functions which include identifying and examining commonalities and differences between patterns and relationships, the same as in the foundation phase. However, the time allocated for this phase is 15 hours in one academic year. As for the weighting, it is precisely the same as with the Foundation Phase i.e. “10 % (Grade 4), 10% (Grade 5) and 10% (Grade 6)” (CAPS, 2011:11).

Within the Senior Phase Mathematics Curriculum (Grades 7-9) the function concept includes the following concepts and skills prescribed by CAPS (DBE, 2011).

“Input and output values

Determine rules for patterns and relationships using:

- flow diagrams,
- tables,
- formulae and
- equations

Equivalent forms

Determine, interpret and justify equivalence of different descriptions of the same relationship or rule presented:

- Verbally
- In flow diagrams
- Formulae
- Equations
- Graphs” (DoE, 2011:22).

The time allocation for this content area for Grades 7, 8 and 9 is nine hours spread over two-quarters (CAPS, 2011). However, the weighting not only differs per phase but also per grade within the Senior Phase. For instance: “25 % for Grade 7, 30 % for Grade 8 and 35 % for Grade 9 learners” (CAPS, 2011:11).

Since this research study includes Deaf and H/H students from the Senior Phase, online mathematics assessments were designed based on the above concepts and skills. During the second, the third phase of this PAR project, online mathematics quizzes were implemented in Grade 8 in 2015 and continued in 2016 with Grade 9 Deaf and H/H learners. I will elaborate more on this in chapter 6.

The next section covers school-based assessments for learners with learning disabilities.

2.9 Assessing students who experience learning disabilities

In South Africa, all students who experience conditions which make learning difficult, whether accommodated in mainstream or special schools, must comply with the assessment standards set out by CAPS (DBE, 2011), NPA (DBE, 2011) as well as the NPPP (DBE, 2011). Although the standard of assessment may not be compromised, the pace and format of the evaluations can be modified to conform to the demands of these learners and provide them with equal opportunities to display the knowledge and skills they have obtained. Accordingly, CAPS (DBE, 2011), within the framework of the NPA (DBE, 2011), offers a framework for learners with “most significant cognitive disabilities, and for other students who experience BTL, who may need

alternate ways in which to demonstrate whether they have attained knowledge, concepts, and skills. It also provides a mechanism that ensures that these learners are included in an educational accountability system” (NPA, 2011:30). These mechanisms are referred to as assessment concessions.

Firstly, I will describe the different types of assessment concessions. Secondly, I will provide a detailed discussion on each assessment concession. Thirdly, I will highlight which assessment concession this research study is based upon as well as the rationale for choosing the particular assessment concession.

2.10 Assessment concessions

Since the adoption of Curriculum 2005 Assessment Guidelines for inclusion (DoE, 2002) it was envisioned that concessions should be made to provide learners with BTL the right to benefit from educational practices. Similarly, the publication of the Guidelines for responding to student diversity in the classroom through curriculum and assessment policy statements (DBE, 2011) further proposed that students with learning barriers should have equal access to classroom assessment and be able to showcase their knowledge and skills. Furthermore, the DoE (2001) claims that the school curriculum can present significant obstacles in the case of teaching and learning and highlights that “BTL arise from the different aspects of the curriculum such as the content, the language, classroom organization, teaching methodologies, pace of teaching and time available to complete the curriculum, teaching and learning support materials and assessment” (DoE, 2011:4).

As a result, curriculum concessions are provided to learners who find it difficult to master the content under standardized circumstances i.e. concessions for Deaf students includes the following:

- 2 Official languages in the IP and SP, in the case of Deaf students.
- Deaf students only need to pass one of these official languages at the First additional language level (level 3) and pass the second official language at level 2 (NPPP, 2011).

Assessment concessions, on the other hand, include assessment accommodations and assessment adaptations/assessment modifications also referred to as alternate assessment (Alant & Casey, 2005). These concessions will be discussed in detail below.

2.11 Assessment accommodation

Assessment accommodation is a method or a procedure to grant learners with learning disabilities access to state and district assessments by removing the barriers their disability present. Cawthon argues that assessment accommodation is “range of changes to test administration and test content; they are designed to eliminate factors that penalize students because of their disability, resulting in assessment scores that do not represent their content knowledge” (2006:338). In other words, the aim is to increase access to evaluation and not reduce the standard and hence invalidate the inferences of the results. According to Tindal and Ketterlin-Geller (2004), assessment accommodation is the administration of an evaluation by eliminating anything that denies learners with disabilities access to tests. They further argue that these accommodations should be included in state policies and should not in any way change what is being measured. My view on assessment accommodation is the modification of the standard condition under which the assessment is being taken without compromising the items being tested and thus nullifying the results obtained by the learners.

Assessment accommodation should not lead to amplified test scores of learners with disabilities. Furthermore, it should measure the same items as for physically challenged and non-disabled students. Another important aspect is that teachers need to familiarize themselves with state policies regarding the different types of assessment accommodations and which accommodations can be used in state and district assessments.

2.11.1 Different categories of assessment accommodations

Assessment accommodations are divided into different categories. These groups include presentation accommodation, response accommodation, settings accommodation, and timing and

scheduling accommodation. Thompson, Morse, Sharpe and Hall (2005) provide a comprehensive description of each of these categories.

- “Presentation Accommodations—Allow students to access information in ways that do not require them to read standard print visually. These alternate modes of access are auditory, multi-sensory, tactile, and visual.
- Response Accommodations—Allow students to complete activities, assignments, and assessments in different ways or to solve or organize problems using some assistive device or organizer.
- Setting Accommodations—Change the location in which a test or assignment is given or the conditions of the assessment setting.
- Timing and Scheduling Accommodations—Increase the allowable length of time to complete an assessment or assignment and perhaps change the way the time is organized” (Thompson, Morse, Sharpe & Sharon Hall, 2005:14).

Within each assessment accommodation category there exist different types of assessment accommodations. These will now be discussed.

2.11.2 Different types of assessment accommodations

Various types of assessment accommodation are used for learners with learning disabilities. These assessment accommodations include:

2.11.2.1 Extended time

This accommodation comprises of adding an extra amount of time to the initially allocated time to administer the test. Mostly extra time means, adding a half an hour more or a full length of the time more needed by the learner to complete the test.

2.11.2.2 Small group/individual administration

The standard context of taking test or exams is usually either in a classroom or a structured environment. This accommodation implies that the test is administered either in smaller groups by reducing any distractions that might hinder physically challenged learners from gaining access to the test. Furthermore, it can also include taking the test individually or in a more structured environment like a separate room.

2.11.2.3 Test directions interpreted

These accommodations imply that the assessment instructions are read out loud by the teacher. Accordingly, this also means that for Deaf and H/H learners, the test directions are in the form of Sign Language administered by an interpreter.

2.11.2.4 Test items read aloud

This accommodation allows the test administrator to read the test questions aloud. The learners respond to the questions by completing a bubble sheet, especially in the case of multiple choice questions.

2.11.2.5 Test items interpreted

This accommodation includes the test administrator translating the test items into Sign Language (in the case of Deaf and H/H learners). Accordingly, this accommodation is dependent on the students' "language preference and test context" (Cawthon, 2010:188).

2.11.2.6 Student signs response

This assessment accommodation permits students to answer questions within the assessment in a language of their choice, whether it is Sign Language or any other language. An interpreter or a scribe translates the answers into sound English or Afrikaans and captures it in written format.

As mentioned in Chapter 1(1.6.3) assessment accommodation is a term used internationally. South African policy documents refer to it as Alternate or Adaptive Methods of Assessment (AMA) or Special Concessions (NPA, 2011; Circular: 0021/2009, WCED, 2009). On the one hand, AMA refers to the changes made to the presentation, response, settings, timing, and scheduling of the assessment. On the contrary, special concessions include an exemption to an examination on the basis of the learning disabilities of learners as stated in Circular: 0021/2009 (WCED, 2009:1) i.e. “An exemption will be allowed if, based on the specific needs and circumstances of the learner, it will not be expected of the student to meet all the promotion requirements for a particular grade. Exemptions will only be granted in the Languages and Mathematics Learning Areas”.

2.12 Assessment accommodation in practice

This section includes literature relating to the use of different assessment accommodation techniques around the world specific to learners with some disability. It also illuminates on the problems experienced while administering these type of assessment accommodations. Furthermore, it presents literature relating to the use of computer – based mathematics assessment techniques specifically for Deaf and H/H learners and its potential in school mathematics classrooms.

A study conducted by Elbaum (2007) on reading aloud accommodation in mathematics for students with and without disabilities provided impressive results. The participants consisted of 643 grade 4 through 10 learners (with and without disabilities). The study concluded that read aloud as an assessment accommodation not only improved the accomplishments of physically challenged learners in mathematics but also the non-disabled students. The test accommodation favored the students without disabilities more than those with disabilities.

A study was conducted by Lewandowski, Lovett, Parolin, Gordon and Coddling (2007) based on the effects of adding additional time as an assessment accommodation on the mathematics achievements of students with and without ADHD. These researchers found that the experimental group consisting of ADHD learners performed well below the controlled group

(without ADHD) even with extended time accommodation. However, an interesting finding was that with extended time accommodation the ADHD learners reached the same performance level as those students in the control group. This result indicates that providing students with disabilities an accommodation can raise their performance levels in line with learners without any disabilities.

Similarly, Elliott and Marquart (2004) probed the effect of adding more time as an assessment accommodation had on ninety-seven 8th grade students with learning difficulties. Their findings indicate that physically challenged and non-disabled students performed at an equally level when provided with extended time accommodation as well as regular time. However, what they did find was that by providing extended time accommodation to both groups, there was an increment of a number of correct answers to the test. Additionally, they found higher gains in academic skills in learners with disabilities and low performing (mathematics) learners than learners without disabilities.

A study conducted by Cawthon (2011a) on recommendations by teachers on which assessment accommodations to use for Deaf and H/H students provided useful insights. The participants consisted of 372 teachers and other educational, professional ranging from grades K-12. The findings disclosed that the most commonly used assessment accommodation recommended were “extra time, test directions interpreted and test items interpreted” (Cawthon, 2011a:353). Additionally, the findings also claim a distinction of choice of assessment accommodation in different subjects i.e. mathematics and reading (English) as well as the level of proficiency of the learners were in either mathematics and or reading (Cawthon, 2011a).

A study based on the employment of American Sign Language (ASL) as an assessment accommodation in mathematics and reading for Deaf and H/H learners were done by Cawthon, Winton, Garberoglio and Gobble (2011). They conducted a quasi-experimental research with 64 students ranging from grade 5 through 8. The mathematics and reading assessments were translated into Sign Language via a DVD or presented on a computer screen. Furthermore, the learners had to watch the demonstration and answer the question through the use of pencil and paper assessments. The findings concluded that no differences were found through the use of Sign Language as an assessment accommodation. Similar, results were observed by Maihoff, Bosso, Zhang, Fischgrund, Schulz and Carlson (2000). These researchers examined the use of

Sign Language via DVD as an assessment accommodation in mathematics for 19 Deaf learners aged between 10 and 11 years. During the interviews, the students preferred paper and pencil assessments since the DVD version was too slow. However, further analysis of the results indicates that the students could understand the mathematics question clearer through the DVD format.

Qi and Mitchell (2012) argue that Sign language as an assessment accommodation is more appropriate for mathematics assessment than for Language or reading assessments. In my view, it all depends on the construct you are measuring. For example, if you measure multiplication, giving learners a calculator as an accommodation will invalidate the inferences drawn from the results, but using an assessment accommodation type in the form of Sign Language in mathematics word problems will be less questionable. In contrast, when testing reading ability and using an assessment accommodation like Sign Language to remove the obstacles reading present to the Deaf and H/H learners will not measure the construct being tested and therefore invalidate the scores obtained (Cawthon, 2010).

Calhoon, Fuchs, and Hamlett (2000) examined the use of computer-based assessment accommodation for mathematics assessments. This study included 81 learning physically challenged learners ranging from grades 9 through 12. Each of the students engaged in the evaluations under four conditions i.e. standard, read by the teacher, read by a computer and read by a computer with a video component (Calhoon, Fuchs, and Hamlett, 2000). The results indicated that the learners performed better with each of the read aloud conditions as to the standard condition. A similar study conducted by Burch (2002) examined three computer-based assessment accommodation types i.e. text read by a computer, a video representation of the mathematics problem and computer input (either through a computer mouse or any other input device), where learners can input their answer without using pencil and paper. The participants were all grade 4 pupils of which 18 had reading disabilities, 15 learners had reading and mathematics disabilities and 16 learners with no disability. The findings indicated that the 15 students with reading and mathematics disabilities obtained a scoring spike with the use of computer-based accommodation while the performance of the 18 learners with reading disability improved dramatically.

Russell, Kavanaugh, Masters, Higgins and Hoffmann (2009) conducted a study on the use of computer-based mathematics assessment accommodation which included the use of a male or female signing (video) and an animation character signing. This study consisted of 96 grade 8 through 12 Deaf and H/H learners. Although the researchers found no meaningful difference in performance between the two formats, the students reported a preference towards the use of CBAs as an assessment accommodation for mathematics assessment.

As seen from the above empirical evidence, providing assessment accommodation to students with disabilities will not only increase their access to the assessment but might lead to an increase in performance in subjects like mathematics and languages. It indicates the usefulness of CBA as a means to administer assessments.

The next section shed light on alternate assessment for learners with disabilities.

2.13 Alternate Assessment

2.13.1 The origin of Alternate Assessment

Revisions to Individuals with Disabilities Education Improvement Act (IDEIA, 2004) as well as the No Child Left Behind Act (NCLB, 2001) provided a framework for the origin of alternate assessment. These frameworks provided a basis for the inclusion of all learners irrespective of their disabilities to be included in state and district accountability tests. Within these legislations, it is proposed that students with disabilities can engage in assessments in a standardized format, or they may use assessment accommodations. However, in cases where students are unable to participate in formal assessments, even with accommodation an alternate assessment is proposed. Accordingly, IDEA'97 and NCLB (2001) termed alternate assessment as a regular assessment for learners with disabilities.

2.13.2 Alternate assessment defined

The alternate assessment is a procedure or a condition that “allow students who cannot participate in standardized assessments (even with accommodation) to be included in the large-

scale evaluation process” (Cawthon & Wurtz, 2009:156). These assessments are explicitly for learners with severe cognitive disabilities as well as students with other learning disabilities i.e. Deaf and H/H, Blind, etc. (NPA, 2011). Lowrey, Drasgow, Renzaglia and Chezan argue that “Alternate assessment allows for different modes of responding, a different context of assessment, and different content that is still linked to statewide standards” (2007:245). Essentially, this means that assessments are being tailored to accommodate learners with special learning needs.

Different labels have been used for alternate assessments. These include “direct assessment”, “authentic assessment”, “performance assessment and alternative assessment” (Hamayan, 1995:213; Sandford & Hsu, 2013). Although minor distinctions exist between these terms they share two fundamental commonalities, i.e., they are regarded as alternatives to the standard form of assessments, and they measure the performance of learners based on a particular topic or subtopic particular to real world examples (Sandford & Hsu, 2013). In the case of this research study, alternate assessment refers to an alternative to the traditional paper and pencil assessments using online mathematics assessment.

The rationale behind alternate assessment is based on the need to provide learners with disabilities an opportunity to demonstrate what knowledge and skills they have obtained. Furthermore, by including physically challenged students in state and district assessments, policy makers can obtain a blueprint of all students’ performance and not only the performance of learners without disabilities since this was the case while DL was not included in standardized testing. Alternate assessment can also contribute in gaining access to the general curriculum. Essentially this means that teachers and policy makers will become more aware of the learning difficulties learners with disabilities experience and in turn provide access to more resources and educators might adapt their teaching and assessment practices. Alternate assessment according to the DoE is “to minimize the impact of a range of intrinsic and extrinsic barriers upon the assessment performance of the learner” (DoE, 2002:9).

The section below provides an overview of the three different categories of alternate assessments.

2.13.3 Alternate assessment prescribed by the NPA

In line with the NCLB (2001) and IDEIA (2004), the NPA (DBE, 2011) mandates 3 categories of alternate assessments i.e. “Alternate Assessments Based on Alternate Attainment of Knowledge (content, concepts and skills), Alternate Assessment Based on Modified Attainment of Knowledge (content, concepts and skills) and Alternate Assessments Based on Grade-level Attainment of Knowledge (content, concepts and skills)” (NPA, 2011:36). Each of these will now be discussed.

2.13.3.1 Alternate Assessments Based on Alternate Attainment of Knowledge (content, concepts, and skills)

The NPA (DBE, 2011) prescribes this category of alternate assessment for learners with a substantial cognitive disability. Furthermore, it includes subject content in line with the grade level assessment. However, the content covered by these type of evaluations is at a “reduced depth, breadth, and complexity” (NPA, 2011:30). In other words, learners are assessed on what they can achieve at their highest level. These assessments are aimed at students with severe intellectual disabilities participating in either general or special education. Accordingly, the United States Education Department refers to this as alternate assessment based on alternate achievements which include "an expectation of performance that differs in complexity from a grade-level achievement standard" (2005a:20).

2.13.3.2 Alternate Assessment Based on Modified Attainment of Knowledge (content, concepts, and skills)

These assessments are dictated for learners with “moderate intellectual disabilities as well as Deaf and H/H students” (NPA, 2011:31). Although these students can “work on grade-level content covered by the general assessment, they are provided with more time to master the content” (NPA, 2011:31). In other words, these type of assessments evaluates whether learners have mastered the material at grade-level, given that more time is added while doing these assessments.

2.13.3.3 Alternate Assessments Based on Grade-level Attainment of Knowledge (content, concepts, and skills)

This category of assessments is aimed at “learners with disabilities or learning difficulties, which needs testing formats or procedures that provide them with equal opportunities to demonstrate their attainment of content which is at the same grade-level as the general assessment” (NPA, 2011:31). Essentially this means that the format of the assessments is modified or adapted, but still in line with state standards and at the same grade level, for all learners to gain access to assessments. These type of assessments are for learners who are blind, Deaf or H/H, learners who have communication and or physical disabilities and students that are dyslexic. The current research study is in line with this category of alternate assessment. Within these categories there exist different types of alternate assessments which will be discussed in the next section.

2.13.4 Different types of alternate assessments

2.13.4.1 Out of level testing

This alternate assessment model entails the administration of standardized assessment at above or below the current age level (or grade level) of the Deaf and H/H learners’ peers. However, a primary concern is how to score this type of alternate assessment. For example, research has found pupils participating in standardized assessment below the grade or age level “may not be equally represented in NCLB accountability frameworks” (Cawthon, 2006:354). In other words, the validity of scores used in such type of alternate assessments is being questioned. For this reason, learners using these type of alternate assessments will be categorized as students that are incapable of participating in standardized assessment, even with some form of accommodation.

2.13.4.2 Checklists

During these types of alternate assessments, teachers complete a checklist indicating whether learners have met the required outcomes or mastered the specific skills required at their grade

level. A teacher or a knowledgeable other must complete these lists by indicating how many skills the learners were able to perform as well as under what circumstances they acquired these skills (Quenemoen, Thompson & Thurlow, 2003).

2.13.4.3 Student work samples

This model of alternate assessment includes the collection of learners' work samples to provide evidence that students mastered the outcomes envisioned by the learning program. However, validity is a major concern with these type of alternate assessments. Since these type of assessments take place during instruction and although it might be in line with curriculum standards, evidence cannot be provided that this is, in fact, a valid form of alternate assessment.

2.13.4.4 Curriculum-based alternative

These type of alternate assessments are integrated within the instruction. In other words, the assessments are done throughout the school year either during or after the teaching of the course. Since these forms of alternate assessment consist of classroom activities, the validity of these type of assessments is questioned.

2.13.4.5 Portfolio

This alternate assessment type entails the collection of notes, journals and other documents that can be presented as evidence to showcase that Deaf and H/H learners have achieved the desired outcomes. Accordingly, it makes use of a scoring rubric with predefined scoring criteria (Almond & Case, 2004, Quenemoen, Thompson & Thurlow, 2003). Since this type of assessments is administered during the school year and based on artifacts from learners, its validity is also questioned especially in the case where these types of artifacts cannot be coordinated with curriculum standards. Essentially, this means that although learners score high marks on these activities since it's not in line with curriculum standards, it cannot act as evidence to showcase that learners have indeed achieved the desired outcomes.

2.13.4.6 Observation in a structured setting

This type of alternate assessment includes the observation of Deaf and H/H students in a structured learning environment while they are completing assignments focused on demonstrating the desired outcomes. This alternate assessment type is also called performance assessment (Almond & Case, 2004). These researchers argue that traditional pencil and paper tests or assignments are included in these type of alternate assessments. Moreover, a scoring rubric is used to score learners' accomplishments.

2.13.4.7 Observation in an unstructured setting

Deaf and H/H students are observed while busy with regular classroom activities which focus on attaining the knowledge and skills required of them.

Although these type of alternate assessments are the most commonly used abroad, issues of validity remain a concern. Therefore, a need exists for the development of a quality alternate assessment, one which is embedded within state curriculum standards.

2.13.5 Alternative measures in SA

White Paper 6 (DoE, 2001) presents an alternative assessment framework for learners who experience BTL:

2.13.5.1 Deafness and H/H learners

- “Listening can be supported with non-verbal cues. For example, gestures, signing, lip-reading, facial expressions (don’t overdo it) and pictures to assist with comprehension of vocabulary and concepts. Never assume that the learner has understood what you said; check by asking questions.
- Students who use SASL as a first language receive visual messages and not auditory messages.

- When giving instructions, the tempo and clarity of speech are necessary. Use shorter sentences, less information per sentence (not too wordy), and increase the length of pauses between sentences. Gaining eye contact and lowering the body to the learner's eye level will also help.
- Provide a list of key concepts or vocabulary for new material.
- For learners who need SASL, use an SASL interpreter. Present information with subtitles or in SASL format. If necessary, students can rewind the video to clarify. Subtitles also improve students' reading skills.
- SASL interpreter will provide the voice-over for learners who use SASL.
- Use peer tutoring.
- Use games for drill and practice.
- Use DVDs with subtitles or interpret in SASL.
- Use boards, pictures, posters with words and pictures, overhead projectors, and signs.
- Use of alternative or augmentative communication modes (e.g., signing, miming, gestures, facial expressions, writing, images, graphics and any technological devices).
- Allow more time to complete assignments and tests.
- Allow learners to use a computer or word processor etc. "(DoE, 2001).

2.13.5.2 Learners with learning disabilities

The use of question alternatives in the case of accessing pencil and paper information

- The use of a reader i.e. computer or cd's/DVDs.
- A reader as an examiner.
- Questions being audio-taped.
- The use of a computer with a voice synthesizer.
- Additional time added (DoE, 2008).

2.13.5.3 Learners are having difficulty expressing their knowledge in written format due to spelling and grammar barriers.

- Using a scribe.
- The use of an audiotape or a Dictaphone.
- Computer software with spelling and grammar checker.
- Using a dictionary.
- The use of multiple choice questions or short answer questions as an alternative to long response to questions.
- Providing learners with additional time (DoE, 2008).

2.13.5.4 Learners experiencing difficulties with numbers and numerical concepts

- Using a calculator or a computer to do computations.
- Learner responses can be presented orally to an examiner.
- Additional time added (DoE, 2008).

The above guidelines are congruent to the assessment and support guidelines envisioned by the DoE (2008), SIAS (2014); White Paper 6 (DoE, 2001) and SAQA no. 58 of 1995 which provides support measure to assist learners with BTL gaining access to general assessment practices.

These support measures are captured in Table 2.3 below.

Accommodation or Alternate assessment	Sight barriers	Deaf / H/H	Deaf / Blind	Physical barriers	Learning disabilities	Behavior, anxiety, ADD	Limited Functional speech	Severe BTL
Modifying questions	•	•	•	•	•		•	•
Amanuensis	•	•	•	•	•	•		•

Braille	•		•					
Computer	•	•	•	•	•	•	•	•
Dictaphone	•			•	•			•
Enlarge Print	•			•				•
Oral testing	•	•	•	•	•	•	•	•
Reader	•	•	•	•	•			•
Planning Aid					•	•		•
SAL interpreter		•	•					
Tape-Aid	•			•	•	•	•	•
Braille transcription	•		•					
Video		•					•	

Table 2.3: Support measures to provide learners with BTL access to assessment practices.

Adapted from DoE (2008)

From Table 2.3 above it is evident that the DoE (2008) allows for assessment adaptations which are in line with valid and reliable assessment practices. Accordingly, the current research project sets out to use a combination of these support measures to adapt the traditional paper and pencil assessments. The rationale for using a combination of these different assessment adaptations are grounded in the fact that Deaf and H/H learners also suffer from learning difficulties. In other words, they are facing multiple BTL, hence providing them with an alternative in the form of online mathematics assessments.

The section below covers the administration of alternate assessment for Deaf and H/H learners internationally with particular reference to the South African context.

2.13.6 Alternate assessment in practice

Research findings on the administration of alternate assessment for Deaf and H/H learners especially in mathematics education are very limited. Moreover, results of research on the use of alternate assessment for Deaf and H/H students only focus on statewide accountability tests. Additionally, research on alternate assessment mainly concentrates on students with severe cognitive disabilities as well as making use of “alternate assessment based on alternate achievement standards” (NPA, 2011:36). Consequently, this gap in literature provides inadequate direction for governments and teachers to assess learners with disabilities.

A lack of research also exists on the results of the impact alternate assessments have on Deaf and H/H students’ performance in mathematics. Moreover, while IDEA 97’ promotes the participation of all students, especially those with disabilities, in standardized testing, no “specific direction to states about what an alternate assessment is, what it should look like, or how it should be scored or reported, nor does it specify the type or number of alternate assessment participants” (Thompson & Thurlow, 2000:1). This view is also true for learners with learning disabilities in a South African context.

Kampfer, Horvath, Kleinert and Kearns (2001) conducted a study through the use of a survey which was completed by 206 educators, teaching at special schools in Kentucky. The study was based on the teachers’ time spent on alternate assessment practices and the variables that influence the scores on alternate assessment at their respective special schools. The results of the survey concluded that teachers spend an enormous amount of time planning, administering and attending to individual portfolios outside of the classroom. They concluded that “instructional variables (student involvement, the extent to which portfolio items are embedded into instruction and teacher’s perceived benefit of the portfolio to the student) are strongly related to student scores” (Kampfer, Horvath, Kleinert & Kearns, 2001:361). In other words, alternate assessment should be administered in conjunction with instructional practices. My point here is that alternate assessment should be used in line with classroom teaching and learning and that learners should play an active and engaging role during assessment practices. Primarily, I am

illuminating the importance of connectedness between assessment and teaching and learning. Also, this evaluation should be used to guide education process.

In 2002, Roeber published a report based on the three most commonly used alternate assessment types. These included portfolios, checklists, and performance assessment. Roeber (2002) also discovered that different states use a combination of these alternate assessment techniques to administer and report results of these assessments. For example, states would use the checklist in conjunction with portfolios, where portfolios are used to act as empirical evidence of learners' performance in subjects. Essentially this means that alternate assessment practices differ from state to state since it is modified to conform to the state departments' assessment protocols.

A collection of 19 database peer-reviewed articles based on alternate assessment were published by Browder, Spooner, Algozzine, Ahlgrim-Delzell, Flowers and Karvonen in December 2002. These reports described what researchers and state departments already know about alternate assessments and how to measure learners' academic achievements as well as what they should know. These researchers highlight that insufficient empirical evidence exists based on the effectiveness or whether alternate assessment meets its expectations described in state policies. They conclude their research study by providing states with some guidelines for measuring and attuning their alternate assessment practices for future success.

A study conducted by Cawthon on the use of alternate assessment for 2003 - 2004 school year concluded that "out of level testing, work samples, and curriculum based alternatives" were the most frequently used form of alternate assessments for more than 900 learners attending 71 schools (Cawthon, 2006:354). This researcher also posits that there exists a greater need for schools for Deaf and H/H learners to administer other forms of alternate assessment.

Alant and Casey (2005) conducted a study on the use of assessment concessions in a South African context. Not only did these researchers find limited research done on assessment concessions in a South African context, but they conclude their study by highlighting the importance of assessment concession i.e. alternate assessment or assessment accommodations in the case of learners with disabilities. They further posit that decisions on the use of assessment concessions should focus on: the procedures that need to be followed to make adjustments to

assessments, gathering empirical evidence on the use of assessment concessions and modifying the concessions to examine the changes it reflects in different situations, the validity, and reliability of such assessment concessions and investigating how aligned are the assessment concessions with instructional practices.

Thompson and Thurlow (2003) examined the most commonly used alternate assessment in different states. Their findings indicate that for the 2003 year portfolios were used by 23 out of the 50 states, 15 out of the 50 states used checklists; nine states used performance tasks and four states used IEP's. The respondents in the survey reported unanimously that they accumulate different sources of data to enhance the validity of the test results.

Cawthon and Wurtz (2009) conducted a study on the use of alternate assessment with Deaf and H/H learners specifically on the use of portfolio's, checklists as well as out-of-level testing. The study utilized the "Second National Survey of Assessments and Accommodations for Students who are Deaf and H/H" (Cawthon & Wurtz, 2009:155). The participants consisted of 314 teachers or administrators teaching within Deaf education which included 50% teachers within Deaf education, 20% teachers in mainstream and special schools, 8% administrators as well as 6% acting in different roles. The findings indicate that teachers, students as well as state representatives play a significant role when selections have to be made on the use of alternate assessments. Furthermore, findings suggest that at least a quarter of all the participants signaled that they use all three alternate assessment formats. Moreover, 65% of all the participants preferred portfolios as an alternate assessment form especially in schools for the Deaf. Although states in the United States allow the use of portfolios as an alternate assessment format, there exists no framework (*how, who, what*) for the utilization of a portfolio especially in the case of Deaf and H/H learners.

2.13.7 Critique on the use of assessment accommodation and alternate assessment practices

Bielinski, Thurlow, Ysseldyke, Freidebach, and Freidebach (2001) provide useful insights gained from their study on reading aloud accommodation with students (3rd and 4th grade) with disabilities. Not only did these researchers find that the accommodation didn't modify the difficulty level of the assessments, but it worsened the situation. Although these researchers

present different factors that could have led to these results it still questions the use of reading aloud as a proper measure to allow physically challenged learners access to assessments. Similarly, a study conducted by Weston (2002) indicated that students within the general education presented with reading aloud accommodation got irritated about the time-consuming factor of such an assessment accommodation. Since they could read the question by themselves, waiting for the test administrator to finish reading the question aloud, made them impatient and demotivated them.

A question that's been repeated through all empirical studies on alternate assessment is who should participate in the alternate assessment. Although different debates exist on who should be involved, individual states have policies in place that prescribes the characteristics of participants who are eligible for alternate assessment. In the case of Ohio, they have published an alternate assessment framework for participation for learners with severe cognitive disabilities (Ohio Department of Education, 2015). This framework includes a set of questions which teachers and examiners must pose for learners to be eligible for alternate assessments. Pupils who do not comply with the "YES" on the checklist, will qualify for assessment accommodation.

Another critique against the use of alternate assessment is the issue of validity. Almond and Case posits that "there needs to be documentation that competence on the alternate assessment reflects capabilities and accomplishments in the subject area being assessed. Items, tasks, or indicators designated must represent the domain being tested" (2004:7). Essentially this means that the assessment should test what it is supposed to test. For example, testing learners' multiplication skills with the use of a calculator as an alternate assessment will not produce verifiable results. The USA Education Department claims that to ensure the validity of scores obtained in assessments; states should develop assessments that are in line with curriculum standards and which conform to grade-level testing (USADoE, 2005). They further claim that "States should also define the assessment's measurement constructs precisely and develop accessible test forms that include bias-free test items; simple, clear instructions and procedures; maximum readability and comprehensibility; and optimal legibility... Students with disabilities who are not able to show what they know and can do on the regular grade-level assessment, even with appropriate accommodations, must be assessed with an alternate assessment. Such alternate

assessments may be based on grade-level achievement standards or, for those students with the most significant cognitive disabilities, on alternate achievement standards” (USADoE, 2005:11).

Cawthon (2009) claims that decisions on the use of alternate assessment should be in line with the subject being tested, the learner’s skill level and the language of instruction. Essentially this means that before alternate assessments are conducted, questions based on these factors must be answered i.e. what is the subject being tested, what the learners’ skill level are and what language of instruction are utilized. Cawthon posits that these are all factors that can influence the type of alternate assessment to administer and might further guarantee valid inferences to be drawn from test results.

Lane (1999) on the other hand provides procedures to examine the validity of assessments that evaluate whether learners have achieved the standards set out by state curriculums. She posits that two descriptors are conducive to ascertain the validity of these type of assessments. Firstly, whether the assessment is in line with state curriculum standards. Secondly, the degree to which the curriculum that is offered to learners with disabilities, is in line with these academic standards. In other words, alternate assessment should be underpinned by state academic standards.

Differential boost should also be regarded when administering either assessment accommodation or an alternate assessment. This important issue was highlighted by Lindstrom (2010) in a study based on mathematics accommodation and how it supports the differential boost hypothesis. Differential boost means that a test accommodation or an alternate assessment increases the test scores of those learners, identified as students with BTL, more than learners without BTL. In other words, when students with or without disabilities take tests with either assessment accommodation or alternate assessment and the amplification of test scores are in favor of learners with disabilities, the tests are deemed valid. (Fuchs, Fuchs, and Capizzi, 2005). In line with Lindstrom’s (2010) view that no particular test can guarantee a standard differential boost. I believe that teachers should be responsible for selecting the appropriate test accommodation for their particular context. Although relying only on teachers’ judgments can be problematic administering test accommodations and alternate assessments within a reliable framework might guarantee valid inferences from test scores.

2.14 Assessment accommodation versus Alternate Assessment

An important point to consider is that assessment accommodation allows for access to the assessment or the test with the aim of reducing barriers caused by learning disabilities. The purpose is not to subjugate learning prospects. The aim should be that learners with learning disabilities can achieve grade level outcomes and can be assessed on state curriculum standards. On the other hand, alternate assessment refers to the modification or the alteration of test items which in turn reduces the learning prospects of physically challenged learners. Mainly it includes reducing the content students need to learn, reducing assessments or parts of the assessments for pupils to only answer easy questions. Thompson, Morse, Sharpe and Hall (2005) claim that “Providing modifications to students during classroom instruction and classroom assessments may have the unintended consequence of reducing their opportunity to learn critical content. If students have not had access to significant, assessed content, they may be at risk for not meeting graduation requirements” (p.15).

On the one hand, the current research study is in line with assessment accommodations since it removes the barriers paper and pencil mathematics assessments through the use of online mathematics assessment. On the other hand, it is also in line with alternate assessment based on grade-level attainment of knowledge since the language, input and capturing of results will be modified but aligned with curriculum standards set out by the NCS (DBE, 2011). It is thus a hybrid between assessment accommodation and alternate assessment. A detailed outline of how this “hybrid” online mathematics assessment was structured and implemented will be discussed in chapter 5.

2.15 Summary

The discussions in the above sections provide a clear picture of the use of mathematics assessment prescribed by IDEA '97; NCLB (2001) in the United States and the NCS (DBE, 2011) in South Africa; as well as the different concessions that can be used for learners experiencing BTL. Although there are no clear set of guidelines to indicate the “*how, who* and

what” of alternate assessment it is set in stone by national and international legislations and should thus be implemented by all schools.

The next chapter provides a detailed description of the learning theories which underpin this research study.

CHAPTER 3: LEARNING THEORIES SPECIFIC TO DEAF/HH LEARNERS AND ICTS

3.1 Introduction

This section presents the learning theories underpinned by the current research study as well as the rationale for choosing the particular learning theories. Firstly, it provides a detailed account of how Deaf and H/H learners learn in general as well as how they learn mathematics. Secondly, it presents an account of Constructivism and Mediated Learning Experience (MLE) as the underlying learning theories of the current research study. Thirdly, it illuminates the role computers play in MLE as well as the role online assessment can play in exposing Deaf and H/H learners' thinking processes specific to mathematics learning.

3.2 How Deaf students learn

Before any discussion on teaching and learning of Deaf and H/H students can commence we first need to highlight what Deaf and H/H means. For this reason, I want to elaborate on the two concepts i.e. Deafness and Hard of Hearing.

3.2.1 Deafness

Deafness refers to an individual with a hearing impairment of about 70 dB ISO or higher, which makes it impossible to comprehend voice communication. To understand this one first, need to know what hearing is. The human ear consists of three sections i.e. outer ear (pinna), middle ear and the inner ear. All three parts work together to perceive sound. As for the pinna, it accumulates sound waves and moves it through the ear canal which leads to the middle ear. The eardrum is situated within the middle ear and starts to vibrate when the sound waves reach it. While vibrating, it sets the three bones called the hammer, anvil, and stirrup in motion which in turn directs the sound waves further into the inner ear. The vibrations set off by the sound waves

moves towards a liquid filled and hairy cochlea. These waves move over the two types of hair cells called the outer and inner hair cells. While the outer hair cells amplify the sound, the inner hair cells transfer sound to nerve responsible for hearing and from there it is sent to the brain which grants you the possibility to hear (Myklebust, 1964, Marschark, 1997).

The above is a naturally occurring process within hearing individuals. However, within Deaf and H/H learners it is a different picture. Different categories of hearing loss can be present in Deaf and H/H individuals such as conductive, sensory, neural and central hearing loss (Marschark, 1997).

Conductive hearing loss occur when defects arise either with the outer ear or the middle ear. This type of hearing loss is most often temporary and might be treated medically. *Sensory hearing loss*, on the other hand, occurs when the cochlea isn't functioning properly due to either damage to the inner or outer hair cells. When this problem is present, it influences the hearing permanently. *Neural hearing loss* occurs when the message from the inner ear to the brain becomes distorted. This type of hearing loss happens when the inner hair cells transfer the sound information to the sound nerve; no sound information is sent to the brain due to damage to the sound nerve. *Central hearing loss* occurs when there is nothing wrong with the cochlea. However, the part of the brain that receives the audio information is damaged, and therefore the sound never reaches the brain to perceive sound (Myklebust, 1964, Marschark, 1997).

Essentially, this means that learners falling into the different categories of deafness are those that experience an auditory impairment and whose sense of hearing isn't functioning at all and therefore unable to perceive sound (Myklebust, 1964, Myklebust, 1997, Marschark, 1997).

Moreover, not even the use of a hearing aid can assist such an individual to gain access to speech (Moores, 2000). In other words, Deaf learners are unable to become aware of sound i.e. voice or speech, through their hearing senses. Accordingly, these individuals are forced to use another type of communication method to express themselves and to understand one another. Not being able to hear and not being able to be understood has significant consequences on Deaf learner's ability to learning.

Looking at 70 decibels (dB) again, it refers to the unit to measure the level of sound. As for the noise level, it denotes the loudness or volume of the sound. The perception of sound for a hearing person is around 0 dB. In other words, a hearing person can determine a noise at 0 dB.

Consequently, this means that an increment in dB of a sound an individual cannot perceive indicates a hearing impairment at some level. These levels of Deafness are categorized as mild (26 – 40 dB), moderate (41 – 55 dB), moderate to severe (56 – 70dB) and profound (91dB +) (Andrews, Leigh & Weiner, 2004: 15-20).

3.2.2 Hard of Hearing

Hard of Hearing is the term used for learners who has a hearing loss of between 35 and 69 Db ISO. Although H/H is a subcategory of Deafness, learners characterized as H/H can partially perceive speech or sound through their hearing senses either with or without assistive devices, i.e. hearing aid, bone relay or a cochlear implant (Berg & Fletcher, 1970).

3.3 Mathematics teaching and learning in the case of Deaf and H/H learners

This section sheds light on possible factors influencing teaching and learning of mathematics in the case of Deaf and H/H learners. It includes literature relating to external factors influencing Deaf and H/H learners' low performance in school mathematics. Three themes, i.e. informal learning, teaching methods and the language of communication and instruction, are described and in which way it influences teaching and learning of school mathematics in the case of Deaf and H/H learners.

Evidence based on Deaf students' low performance in mathematics informs us that it is not underpinned by hearing loss (Nunes & Moreno, 1998) per se. Pagliaro's (2006) research indicates that low achievement in mathematics might be the result of a lack of incidental learning, teaching methods and the language of communication and instruction. According to Pagliaro (2006), these three factors influence the way Deaf and H/H learners perform in mathematics and by addressing these factors, one might elevate Deaf and H/H students' mathematics understanding. These findings have significant implications for the broader domain of learning for Deaf students. These three factors will be discussed below.

3.3.1 Informal learning

Deaf students are entirely excluded from related learning experiences. In other words, while their hearing counterparts are exposed to some mathematics vocabulary in an informal environment, Deaf learners are excluded from learning that takes place in an informal environment. Accordingly, while hearing pupils enter formal education with a vast knowledge base of mathematics vocabulary, it is Deaf learner's first experience with these words/phrases. Furthermore, while hearing students already have some experience with these concepts and might be able to transfer it to other situations, these ideas still need to be learned by Deaf learners. As a result, Deaf students commence their formal education with a disadvantage due to a lack of informal learning (Pagliaro, 2006).

3.3.2 Teaching methods

Deaf students find it difficult to grasp complex mathematical concepts and procedures (Pagliaro, 2006). Accordingly, teachers adopt a pragmatic view of Deaf students and tend to eliminate mathematics operations that challenge Deaf learners on higher order thinking. For example, in lower grades, teachers would most definitely skip mathematics problems that require reading and interpretation issues to Deaf students (Pagliaro, 2006). Therefore, mathematics words problems will thus be eliminated from classroom teaching, and hence Deaf students are excluded from this any associated metacognitive experiences. As a result, the teaching and learning of school mathematics for Deaf students occur on a basic level. For example, the curriculum content is taught from a textbook perspective and therefore ignoring real world problems. Accordingly, rote learning and memorization of mathematics concepts, formulas and procedures still dominate classroom teaching and learning.

3.3.3 The language of communication and instruction

Research on Deaf learners' low achievements in mathematics indicates that language is a determining factor (Barham & Bishop, 1991; Kelly & Mousely, 1999; Kidd & Lamb, 1993; Kidd, Madsen, & Lamb, 1993; Nunes & Moreno, 2002). Furthermore, these researchers agree

that Deaf learners not only struggle with comprehension issues when confronted with mathematics texts, but they also conclude that reading is one other obstacle standing in the way of achieving higher marks in school mathematics. This belief is based on the divergence of Sign Language and Afrikaans/English (Damon, 2015).

Firstly, the structure of Sign Language and Afrikaans/English language differ. Afrikaans/English sentence structure follow a linear structure i.e. subject, verb, and object. In many cases adjectives, adverbs and prepositions are used. In contrast, Sign Language is more visually based, making use of facial expressions, hand gestures, body movements, position, and placements. Additionally, for some words in a Sign Language sentence, fingerspelling is used as for the rest, a sign is used.

Secondly, Afrikaans/English is not the home language of these learners (Berent & Kelly, 2008). Sign Language is the home language of Deaf students, and they use it to more than 90% of the day to communicate with either their friends or family. Essentially, this means that Deaf and H/H learners are required to learn in a language different from their home language, and Afrikaans/English becomes their second language and hence no fully developed mother tongue (Berent & Kelly, 2008). Not only does this issue bring about comprehension problems, but it also excludes them from expressing themselves in a language they understand.

To elaborate on this matter further, Deaf and H/H learners do not have the Afrikaans/English vocabulary as their hearing counterparts to express themselves. This phenomenon is mainly due to inaccessible Afrikaans/English content either from televisions, radios and other types of media that communicate information pitched at the hearing world. Accordingly, when they enter school, they have little or no Afrikaans/English vocabulary to utilize. Since the medium of instruction is either Afrikaans or English (Grades R-3) and Afrikaans and English (Grades 4-9), it assumes that Deaf and H/H learners are profound in either language, which is not the case. This dilemma affects not only their communication, comprehension, and learning but also their reading as well (Drigas, Kouremenos, Kouremenos & Vrettaros, 2005). It also has disastrous effects on learning and understanding school mathematics. In other words, if learners can't read, they can't understand or comprehend and thus can't acquire knowledge and as a result, cannot learn. Researchers (Kelly, Lang & Pagliaro, 2003) have found that low proficiency in English (Afrikaans as well, from my experience, see Damon, 2015) is a contributing factor in Deaf and

H/H learners' poor performance in school mathematics especially solving mathematics word problems.

Thirdly, Sign Language is not yet recognized as an official language in SA. Moreover, it has only been adopted as a learning area within schools for the Deaf as from this year. However, the inception of South African Sign Language (SASL) as a learning area only applies to the Foundation Phase (Grades R-3) and grades four and nine irrespectively. So, only a few learners have access to this privilege, which on the other hand excludes more than 75% of Deaf students. In other words, not only do Deaf and H/H students need to learn mathematics by overcoming their disability, but they are also presented with mathematics teaching and learning in a language different to their home language.

In short, these three factors play a significant role in Deaf and H/H learners teaching and learning of mathematics. On the one hand, they present obstacles which can lead to poor performance in mathematics and on the contrary little has been done to overcome or address these barriers other than frameworks in policy documents.

The next section provides a detailed account of the learning theories underpinned by the current research study.

3.4 Learning theories specific to mathematics education

Before a definition of learning theories can be provided, we first need to look at the definition of learning? Although different definitions of knowledge acquisition exist, the definition that this research study follows is well captured by Schunk (2011:3) which posits that “Learning is an enduring change in behavior, or in the capacity to behave in a given fashion which results from practice or other forms of experience.” Three concepts are noteworthy about this excerpt i.e. learning brings about change, hence learning means you obtained new knowledge or skills to enable you to do things. Secondly, learning is enduring, which means that learning can extend beyond boundaries. Although this can be argued, the deficiency to learn anything can be rectified by intervention strategies. Thirdly, learning happens through your experience, which means an increase in exposure results in an increase in knowledge. Although Schunk (2011;

Schunk, 2012) agrees with this view, he posits that it also means that an increase in negative experiences does not lead to an increase in learning but increasing the negative behavior.

Learning theories exemplify how learning occurs and what influences the process of learning. Similarly, they also highlight whether learning materializes within the individual or is affected by external conditions.

Van de Walle, Karp, and Bay-Williams (2013) posit that constructivism, together with social constructivism are the most frequently applied learning theories within the field of mathematics education. According to these researchers, utilizing constructivism as a learning theory will provide researchers with an immanent perspective of how learners obtain knowledge. More specifically, what happens in his/her mind when presented with new insights? How do they process the new knowledge? Essentially, this also means that researcher will obtain insights into learners' subjective thought processes and in return might present researchers with useful data on how students learn. In contrast, utilizing social constructivism as a learning theory, researchers can obtain valuable information of how the environment imposes on students' learning. To put it succinctly, mathematics understanding relies not only on the perception and elaboration of mathematics content but also in what way the learning environment regulates mathematics education. The current research study is underpinned by a constructivist philosophy, socio-constructivism as well as computer-mediated learning. These different learning theories specific to mathematics education will now be discussed by highlighting different perspectives on each one.

3.4.1 Constructivism

Even though constructivism is seen by some researchers (Von Glasersfeld in Husen & Postlethwaite, 1989) as a theory of cognition, others contend that it is a process of comprehension or meaning making (Cobb, Yackel, and Wood, 1992). In other words, interpreting information and evaluating it against their existing knowledge. Both these views highlight the importance of the individuals' cognitive structures in coming to know. On the one hand, cognitive structures are acts of evaluating resemblance, by reflecting what is familiar and what isn't (Garner, 2007). The thought processes people use to understand information. For

example, when you are faced with new data, the first thing you do is try to make the connection between what you already know i.e. existing knowledge and the new knowledge. In an ordinary mathematics classroom i.e. no Deaf or H/H learners, one can ask students to look at a problem and identify things they already know about it. In this way, students are asked to focus on what is familiar or what they already know. On the other hand, cognitive structures encapsulate the dismantling of data and integrating the parts with existing knowledge (Garner, 2007).

Essentially, these views are based on the premise that learners don't come to class as empty containers in need of a "top up". They already have their preset ideas and utilizes these ideas to make meaning of what they experience. In other words, teachers need to take their prior knowledge of content into consideration when new content is presented. So, how do you measure cognitive structures? Baird, Fensham, Gunstone and White (1991) is of the view that through reflection and self-assessment teacher can become aware of the development of cognitive structures within learners.

Alternatively, Tsai and Huang (2002) posit that a poorly developed cognitive structure as a result of bits and pieces of information with no real connection can lead to ineffective data processing and knowledge acquisition which in turn can negatively influence your mathematics performance. On the contrary, a well-developed cognitive structure also enables them to learn underlying principles of a phenomenon and generalize these principles to a new learning experience. Blake and Pope (2008) coined the process of making the connection, drawing conclusions and finding underlying principles to generalize to new situations "operative knowledge" (p.59). Operative knowledge is concerned with the modification of students' cognitive structures which results in knowledge creation.

For some researchers (Piaget, 1951) modifying the cognitive structures of an individual can only occur when a balance exists between the activity of the person on the learning environment and contrariwise. He further posits that when your internal perception of the world corresponds to the external environment, in other words, when the concepts and actions you experienced is altered by new experiences of the world, you become more intelligent which he defines as "the state of equilibrium towards which tend all the successive adaptations of sensory-motor and cognitive nature, as well as all assimilatory and accommodatory interactions between the organism and the environment" (Piaget, 1951:11).

Piaget (1951) further believes that the modification of an individuals' cognitive structures can only be achieved through processes of assimilation and accommodation. On the one hand, assimilation refers to modifying the concepts and actions of the environment and making it congruent to your current cognition. On the other hand, accommodation refers to the modification of your thinking processes based upon your interaction with the environment. In other words, an individual can rearrange his/her thought processes using new knowledge and adapt his "old view" of knowing to a "new excellent view" of the world.

The next section describes social constructivism as a learning theory.

3.4.2 Social Constructivism

Proponents of Social Constructivism (Mead, 1934; Berger & Luckman, 1991; Bishop, 1985; Gergen, 1985; Goldin, 1990; Ernest, 1991; Ernest, 1993; von Glasersfeld, 1995; Honebein, 1996; Ernest, 1999) believe that the process of learning is well situated in culture and that knowledge is constructed within a social context (Kim, 2001). Therefore, social constructivists have different perspectives surrounding the view of reality, the manner in which knowledge is constructed and how learning occurs.

Firstly, social constructivist believes that reality only exists because of the individual's experience and when there is no action on the part of the person, no reality exists. Secondly, they believe that knowledge is a byproduct of human activity and that this knowledge can only be constructed in a social and cultural context (Ernest, 1999; Kim, 2001). In other words, the conception of knowledge is born out of human interaction with each other and the environment and vice versa. Thirdly, social constructivists are of the view that purposeful learning can only occur through the child's social and cultural participation (Kim, 2001). According to this view, learning does not only happen by altering the individual's cognitive structures, nor by imposing external learning experiences on the person and thus modifying his/her behavior but through well-orchestrated interaction with one another and interaction with the environment (Davidson-Shivers & Rasmussen, 2006).

Vygotsky is a cultural historical theorist, who proposes a mechanism for learning based on "semiotic mediation" in the ZPD (Van de Walle et al., 2013:20). This process refers to the use of

socially constructed instruments by members of culture to express meaning. For example, teachers, parents or more knowledgeable others transfer concepts and ideas they have obtained through experience and interaction to learners/children. These individuals on their part make meaning of these concepts and ideas and can generalize it to more complex situations. However, the process of semiotic mediation is only conducive to a meaningful learning environment.

Vygotsky coins this meaningful learning environment, the zone of proximal development (Chaiklin, 2003). The zone of proximal development (ZPD) suggests the interaction between a teacher/parent i.e. one with advanced knowledge and skills, and a child/learner i.e. one that lacks advanced knowledge and expertise, in such a way that the latter become sufficiently skilled and knowledgeable due to this interaction. Essentially, this means that the teacher and learners or the parent and the child work together while the teacher and parent mediate the learning process, intentionally steering the students/child in a direction that guarantees meaningful learning.

The above views on social constructivism depict learning as a social process and that it only occurs in a purposeful learning environment. Moreover, sense making is achieved by an individual through interaction with other people and the environment. Since constructivism and social constructivism underpin the current research study, the online learning environment was created with these principles in mind. These principles will be discussed in detail in chapter 5.

The next section focuses on the mathematical epistemology this study is influenced by and the rationale for choosing such a philosophy.

3.5 Absolutist philosophy

The philosophical assumption, absolutists, hold, is that mathematical knowledge is entirely inviolable. In other words, this view highlights that mathematics is a kind of knowledge that is separated from reality as well as detached from one particular context (Ernest, 1991).

Furthermore, Ernest (1991) claims that an absolutist view of mathematics is that it dictates as being a representation of factual reality and that it can achieve the desired goals, hence underpinned by objectivity. As a result, mathematics is viewed as a set of truths that cannot be questioned. In my opinion, the absolutist philosophy is more prescriptive in nature and denies

being embodied within a social or cultural context. Moreover, this view presupposes that mathematics is more rigid in nature.

Toumasis (1997) posits that according to the absolutist view of mathematics, mathematical knowledge is the most certain truth to all humans and that mathematical knowledge has its creation through “deductive reasoning” (p. 319). Essentially, this means that mathematical knowledge constitutes analytic knowledge based upon rational thought processes and denies knowledge abstracted from observation.

3.5.1 Absolutist learning approach

According to this view, learning occurs through direct instruction. In other words, mathematical truths are being transferred from teachers to learners via direct teaching methods in which the learners have to memorize the transmitted knowledge (Toumasis, 1997). Learners are thus passive listeners, waiting for information from their teachers and reproducing this experience by learning facts. Moreover, when learners produce mathematical errors it is seen as a sign of inefficient instruction, and that students haven't learned the facts effectively (Ernest, 1991).

3.5.2 Absolutist teaching approach

Conforming to the belief of absolutists is assuming the truths of mathematical knowledge, and therefore education is seen as the vehicle to transfer mathematical knowledge (facts) into the learners' brains. Accordingly, this view identifies the teacher as the instructor, who teaches mathematics in an integrated approach while making use of textbooks. In other words, learners acquire mathematical proofs, rules, and theorems through lectures by the mathematics teacher (Ernest, 1991).

3.6 The philosophy of Fallibilism

According to the philosophy of fallibilism, mathematics is the product of social interaction within a mathematics community (Ernest, 1991). Since mathematical knowledge is created

within a mathematics community, its roots are founded within the residing culture and history, which further impinge on its validity. As a result, mathematics is envisioned as weak and are receptive for modification (Ernest, 1991). In other words, the philosophy of fallibilism refers to the likelihood of humans to make errors in their process of knowledge construction.

Furthermore, it is also of the view that even when real knowledge is constructed, the underlying assumptions that underpin their knowledge development can still be flawed which can also lead to errors. Mostly, this view highlights that knowledge can be interpreted incorrectly and that in the case of any knowledge claims you should be mindful of its defects which can question its validity.

The fallibilists philosophical view is in line with CAPS (DoE, 2011), which provides a description of what mathematics is i.e. “Mathematics is a language that makes use of symbols and notations to describe numerical, geometric and graphical relationships. It is a human activity that involves observing, representing and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves. It helps developmental processes that enhances logical and critical thinking, accuracy and problems-solving that will contribute in decision-making” (DoE, 2011:8) as well as in line with the National Curriculum Statement Grade 10 – 12 which states that “Mathematics is developed and contested over time through both language and symbols by social interaction and thus open to change” DoE, 2003a:9). It is thus apparent that a fallibilist philosophy is embedded in the NCS (2011).

3.6.1 Fallibilist learning approach

The fallibilist theory is the view that mathematics is a product of social interaction. Therefore each learner is seen as an extension of the community they belong to and thus investigators of that community. Therefore, through inquiry, self-reflection, and investigation into mathematical problems, learners obtain mathematical truths and hence their knowledge construction (Toumasis, 1997). Moreover, since mathematical queries underscore this view, learning is embedded with probing, systematic searches, and uncovering of mathematical truths through either game, peer projects or discussions. Furthermore, mistakes are seen as an opportunity for learning and therefore alternate views are encouraged to eradicate any misconceptions.

3.6.2 Fallibilist teaching approach

Toumasis (1997) claims that according to the fallibilist teaching approach educators must provide conditions conducive to learning. These conditions are executed through offering learners with adequate learning material and administering it in such a fashion that it encourages investigations from the learners. In other words, these teaching materials are selected on the basis that they will stimulate the mental concentration of students as well as motivate them to pursue time on task. Furthermore, Toumasis (1997) posits that a key feature of this teaching approach is the characteristics of the mental imagery that is being constructed and not so much as whether knowledge is created. Moreover, it is the teacher's duty to distinguish between these mental images and refine them through questioning, meaningful discussions as well as elucidating them. This further emphasizes the fact that the teacher is responsible for conditions that will foster discussions, learners presenting their opinions and other students respecting these views and beliefs.

In sum, then, the fallibilist philosophy focusses on interaction and collaboration which is more in line with what CAPS (DoE, 2011) envisions i.e. the teacher becoming a facilitator as well as learning to revolve around the needs of each learner. On the other hand, the absolutist philosophy foresees learning as a process of knowledge transmission from the teacher to the student. Therefore, the current research study qualifies as following a fallibilist philosophy.

The next section focusses on the contributions of Reuven Feuerstein and how it relates to the current research study.

3.7 Feuerstein and learning

In the following section, I will provide details on Feuerstein's work and its relevance to the present study. Firstly, I will provide a brief history on the work of Feuerstein. Secondly, a description of his Instrumental Enrichment (IE) program, as well as his theory on Structural Cognitive Modifiability, follows. Finally, I will provide a detailed review on his Mediated Learning Experience (MLE) which also includes the characteristics of MLE.

Reuven Feuerstein, an Israeli psychologist, formulated Mediated Learning Experience (MLE) as a theory between 1950 and 1963 while working with children who were socially, culturally and intellectually devastated by the negative impact of the Holocaust. His experience with these learners provided him with useful insight about “culturally different and culturally deprived children” (Feuerstein, 1980).

Feuerstein, Klein, and Tannenbaum (1994) argue that the primary distinction between culturally diverse and culturally deprived learners are their ability “to benefit from direct exposure to stimuli “(Feuerstein et al., 1994:5). Moreover, being culturally deprived denotes not benefitting from direct exposure and the necessity for assistance in learning. Furthermore, Feuerstein (1980) argues that cultural deprivation is the result of the absence of mediated learning experience. In other words, what Feuerstein is saying is that learners who are culturally deprived will need assistance in learning how to learn and as well as their metacognitive processes, hence the need for mediated learning experience.

While distinguishing between ‘culturally different’ and ‘culturally deprived’, Feuerstein delineates culture as a vehicle to mediate knowledge, beliefs and values from one ‘genesis’ to another. In other words, knowledge, beliefs, and values are being transmitted within a culture from one generation to another. Accordingly, when no mediation of knowledge, values, and beliefs occurs, he refers to it as cultural deprivation. On the other hand, being culturally different denotes the difference in the norms of one group about the trends within a society (Feuerstein et al., 1994). This view has significant implications for Deaf and H/H learners especially in the instances where parents or teachers do not use sign language in the early stages of the Deaf child’s development. Essentially this means that knowledge, values, and beliefs cannot be mediated, and the Deaf child falls into the category of the culturally deprived.

3.7.1 Instrumental Enrichment (IE)

Instrumental Enrichment is a program designed by Feuerstein to provide learners with a meaningful learning experience through the use of chunks of information. IE is underpinned by two distinct components i.e. the instrument (set of exercises) and the instructional approach which is based on MLE. A distinction is made between Feuerstein’s Instrumental Enrichment

(FIE) and Instrumental Enrichment. While the latter refers to any program based on the principles of FIE, the former relies on a set of 14 instruments which includes: “Organization of Dots, Orientation in Space, Analytic Perception, Comparisons and Categorization” (Feuerstein, 1988:209). These tools are pencil and paper based and are administered in units to provide the mediator with control over the modifying of these units.

The rationale behind the inception of FIE rests on the premise that the human brain is not fixed and therefore flexible for change (Feuerstein, 1988). In other words, Feuerstein believes in the elasticity of the brain and that the brain structures and its capacity can be modified through mediation provided a basis for the development of FIE. The intention of FIE is thus to promote the development of metacognitive processes within the individual to provide the individual with a set of cognitive tools “to improve the propensity to learn and to be modified by learning events” (Feuerstein, 1988:211). Moreover, FIE is not as much concerned with the amount of information processed by the individual but how the person processed the information. Essentially, its focus is on how learning has occurred and hence the set of instruments are designed to address the deficient thought processes to the individual and to use the tools to overcome these dysfunctions (Feuerstein, 1988). Therefore, successful implementation of FIE will lead to a person who is capable of knowing how to gain information also but someone who knows how to apply new knowledge and skills and is more efficient in finding solutions to problems.

3.7.2 Structural Cognitive Modifiability (SCM)

The motivation behind the theory of SCM is based on the belief that human cognition can be modified irrespective of one’s age, through a mediated learning experience which can provide individuals with new insights into seeing, experiencing and acting in the world around them. This phenomenon is the case in all three components of MLE. These components include the mediator, the stimuli, and the organism. Not only does the mediator need to become aware of the individual requirements of the organism, but he/she must know how to alter the stimuli to satisfy this need. Therefore, the mediator modifies his instructional strategies to make the incentives more meaningful to the organism. Modification within the mediator and the stimuli results in an opportunity for the organism (individual) to be cognitively modified. In other words,

experiencing the stimuli from a different perspective, not just for immediate use but to utilize the underlying principles and apply it to new situations.

To define SCM, I will be looking at each concept individually.

3.7.2.1 Modifiability

Modifiability means the proclivity of a child to be altered in his actions and ways of thinking through learning from past experiences (Feuerstein *et al.*, 2014). In other words, the individual becomes conscious of his/her past experiences, and if these recent actions resulted in failures, he/she abandons these activities and applies new found knowledge to these experiences to improve his/her actions/behavior. Essentially, this also means that the organism becomes skilled in looking differently at past experiences by gaining new insights into recent approaches or ideas and changing his/her behavior for future use (Feuerstein *et al.*, 2014).

These modifications are made possible by the plasticity or elasticity of our brains (Feuerstein, 1988; Feuerstein *et al.*, 2014). These researchers argue that due to the plasticity of our brains, any experience that is inflicted on an individual will modify the structure of the brain. Accordingly, this means that when any person is presented with a mediated learning experience, it will not only change his/her actions towards the experience but also modify his/her cognitive processes which in turn will lead to a change in behavior towards future experiences. Mostly, modifiability does not refer to the redress of behavior but to the modification of the cognitive structures of an individual, which has a lasting effect on anyone (Seng, 2003).

3.7.2.2 Structural

Due to the plasticity of the human brain, it allows the experience of a person to alter his/her actions towards new experiences. In other words, the human brain is thus influenced by these measures. Furthermore, we refer to this not only as the “mental operations” but also to “the way of projecting to the future” which is also known as the “neural structure” (Feuerstein *et al.*, 2014:88). Primarily, *structural* in structural cognitive modifiability includes the modification of the thinking structures in a way that it will guarantee different behaviors towards future

experiences. Expanding on the concept of *structural*, this also means that any learning experience is not an isolated event but the underlying principles obtained in one experience can be generalized and applied to different experiences.

3.7.2.3 Cognitive

The last concept in the term SCM, *cognitive*, refers to the human brain's capacity to accumulate data through perception, reflection on assembled data, becoming aware of what is happening around you, comparing, categorizing and linking components based on characteristics (Feuerstein et al., 2014). These different functions of the brain are also referred to as cognitive processing. Consider the following: A car and a lorry. They differ not only in size, capacity, usage and maybe color, but they are both means of transport. By comparing these two modes of transportation, a state of connectedness is created. Our cognitive processing allows us to categorize, analyze or make inferences. In other words, while focusing on the car, I am gathering all the characteristics that make up a car and the same for the lorry. Comparing these features on a set of criteria and reasoning which set of criteria should be used to draw conclusions. It is all made possible through cognitive processing.

Cognitive processing consists of three phases. These include the input phase, elaboration phase and the output phase (Feuerstein et al., 2014). Firstly, during the input phase, all the data of a phenomenon is accumulated through perception. Secondly, within the elaboration phase, the data gathered are reflected upon, compared for relatedness and categorized according to a set of rules. Thirdly, the output stage is the final result of the two preceding steps. In other words, this move includes the results by comparing, categorizing and reflecting on the obtained data. These three stages are also referred to as “mental operations” (Feuerstein et al., 2014:142).

Each of these phases can be influenced by deficient functions (Feuerstein et al., 2014). Defective functions also known as deficient cognitive functions (DCF) refers to difficulties an individual experience within certain domains of functioning. For example, Albert Einstein, the mathematician, had difficulty in orientating himself in space. For others, orientating oneself with direction is also a sign of DCF and results in ignoring or getting confused with instructions based on directions i.e. Right, left, etc. (Feuerstein et al., 2014:142). The next section will look at DCF

within each of the three phases.

3.7.3 Dysfunction in the input phase

Dysfunctions in the input phase refer to difficulties the individual can experience when presented with a problem. Since this step includes the perceptual assembling of information, learners who find it difficult to grasp which information is pivotal to solve the problem are referred to as having “blurred or sweeping perception” (Feuerstein et al., 2014:143). Having a “blurred or sweeping perception” results in learners focusing only on one view of the problem and might also result in students ignoring relevant variables of the problem. It can also result in students diagnosing the route to follow to solve the problem incorrectly which in turn exhibits a wrong answer. Feuerstein et al. (2014) argue that students experiencing these dysfunctions may search for answers to problems before even looking at the problem itself. It also creates confusion in students since valuable information about the problem is overlooked and the skill of extracting the correct information to solve the problem is never learned.

The above goes hand in hand with impulsivity. Impulsivity relates to the tendency to start to address a problem without any deliberation. Essentially, it also means that tackling a problem without identifying the key features of the problem and what is being asked of you. In other words, only looking at one dimension of the problem and ignoring all the other aspects of the problem. The question that should be asked is whether these dysfunctions can be rectified and how. One direction to follow to dysfunction within the input level is by providing MLE within the elaboration phase.

3.7.4 Dysfunction in the elaboration phase

The individual first need to acknowledge that a problem does exist. Your belief that a problem exists is based on previous experiences which are compared to the current situation. In other words, when presented with a problem you first reflect on what you already know about the problem. In other words, what do you see? Is it familiar and do you comprehend what you are seeing? As a result, you compare what you know about the problem and only then, the known

becomes visible. The most important aspect here is to make the individual conscious about identifying the problem.

Feuerstein et al. (2014) argue that a means to allow individuals to identify a problem is by asking the right questions. These researchers also argue that when individuals are asked the right questions, it not only keeps them focused but it provides them with opportunities to ignore irrelevant information about the problem. Therefore, it is also important for the individual to formulate the problem in such a manner that a distinction can be made between applicable information and that information that is beside the problem.

3.7.5 Dysfunction in the output phase

Feuerstein et al. (2014:168) argue that dysfunctions in the output phase are contributed due to “blocking,” “trial and error responses,” “lack of verbal tools for communicating” and a “lack of a need for precision at the output.” In other words, although the learners can gather the correct information from the problem (input) and categorize, find relationships between concepts and reflects upon these ideas, they find it difficult to broadcast their results. These researchers argue that this phenomenon can occur in the absence of MLE and that it can be rectified by presenting individuals with mediated learning experiences that address these dysfunctions.

As seen from above, a dysfunction can occur in one or all of these areas which in turn can lead to learners failing to learn anything. The question that should be asked is how we go about modifying the structure of cognition. Feuerstein (1988) believes that cognitive structures can only be amended when an organism is presented with a mediated learning experience which adheres to certain characteristics. The next section will describe in detail such Mediated Learning Experience.

3.8 Mediated Learning Experience (MLE)

This section provides a detailed account of MLE as envisioned by Feuerstein (1988). Firstly, it includes definition relating to MLE. Secondly, it provides literature studies utilizing MLE in different educational settings. It is followed by a distinction between Direct Learning Experience

and MLE. After that, the characteristics of MLE is discussed. The chapter concludes with literature relating to computer-mediated learning.

Feuerstein (1988) defines MLE as the launch of a learning experience by a mediator (teacher, parent, etc.) through the alteration and scaffolding of learning objects (stimuli) and hence making learning more accessible to learners. In other words, making adjustments to the learning experience to make learning more meaningful to students. Accordingly, this view is underpinned by the belief that learning can occur in all learners, although not at an equal rate and that presenting students with individually modified learning experiences might assist in developing their cognitive skills.

MLE also dictates the deliberate intervention of the mediator through changing the thought processes of students by steering them in a direction where they gain other perspectives in a new learning situation and making complex connections (Feuerstein, 1988). Mostly, this refers to a “mediational interaction” between a teacher/mediator and the learner/child (Feuerstein, 1988:57). However, Feuerstein posits that a mediational interaction does not only refer to the *what* and *where* within the interaction but *how* the mediator interacts with each child and how the child is positioned to apply knowledge and skills obtained from one learning experience to another. On the other hand, Feuerstein (1988) and Seng (2003) argues that a lack of MLE can further make way for deficiencies in the learning process of learners. Along the same lines, Kozulin and Presseisen (1995) and Feuerstein et al. (2014) also believes that MLE can provide students with a fair chance to benefit from formal and informal learning experiences.

Various research studies provide evidence on the strengths of MLE. These include studies conducted by Feuerstein, Feuerstein, Falik and Rand (2002) on the use of MLE on 20 individuals with Down’s syndrome. Through the use of Raven’s Colored Progressive Matrices, Standard Progressive Matrices as well as the LPAD, they noticed a spike in higher functions in these individuals as well as enhanced metacognitive processes.

In line with the above research findings were studies performed by Skuy, Gewer, Osrin, Khunou, Fridjhon and Rushton (2002) on the cognitive functions of university students in South Africa. These researchers posit that the application of MLE in university classrooms increased the cognitive and academic functioning of students. Similarly, Seabi, Cockcroft, and Fridjhon (2009) investigated the effects of MLE on 111 engineering students at the University of

Witwatersrand. Their findings conclude that the use of MLE increased not only the students' intellectual functioning but also their academic performance.

A research study was conducted by Seabi and Amod (2009) on the outcome of individual and group mediation for Grade 5 learners. The results conclude that significant differences could be found between the individual mediation and group mediation. Students who experienced individual mediation manifested an increase in cognitive functions as to the students in the group mediation. They also assert that mediation as a form of alternate assessment can be useful especially in the case of students with learning disabilities.

3.8.1 Direct Learning Experience and Mediated Learning Experience

A question that should be asked is whether or not all teaching includes MLE. To answer this question, one has to look at the difference between direct learning experience (DLE) and MLE. DLE includes presenting learners with the learning objects through instruction without any modification. This approach is underpinned by Piaget's S-O-R model in which the individual (O) interacts directly with the learning environment (S) and provides a response (R) (Todor, 2013). In other words, learners are directly involved in the learning environment (stimuli), but they approach the learning objects without transferring acquired knowledge to the new learning objects. Moreover, each learning experience is seen as an isolated event taking place and hence no connections are being made between the mastered content (interaction with previous stimuli) and newly discovered content. Feuerstein (1988) and Todor (2013) posits that DL occurs unintentionally and is not adequate in producing intended learning experiences.

Within the theory of MLE, the mediator aligns the learning objects in a manner that guarantees a learning experience. Accordingly, Feuerstein (1988) utilizes the same S-O-R model of Piaget but modifies it by inserting a mediator between the stimuli (S) and the individual (O) which results in the S-H-O-H-R model. Ultimately, this means that the mediator positions himself between the learning object (stimuli) and the learner (O) by constructing and reconstructing the learning objects. This process can enhance the cognitive skills of students with the purpose of modifying their thought processes (Feuerstein, 1988; Kozulin & Presseisen, 1995; Todor, 2013). Moreover, the frequency of occurrence of MLE can lead to an enhanced experience of DL. In

other words, increased exposure to MLE can provide learners with the skills to learn from any exposure to DLE. On the contrary, minimal exposure to MLE will lead to an isolated learning experience, where the acquisition of applied knowledge and skills are limited.

MLE has to have certain attributes to equip the learners with the cognitive skills to transfer obtained knowledge to new found situations that require more complex thought processes. The next section highlights these qualities especially the ones conducive to the current research study.

3.8.2 The characteristics of MLE

Although language and different types of content adjudicate what kind of interaction is needed, Feuerstein (1988) argues that it is a different case for MLE. For MLE, it doesn't matter what kind of language is used or the different formats of content prescribed, which differentiates MLE from any other interaction. However, MLE does have unique characteristics that guarantee that the interaction that takes place, is trademarked by a mediated learning experience. This include:

1. "Intentionality and reciprocity;
2. Transcendence;
3. Mediation of meaning;
4. Mediation of confidence;
5. Mediated regulation and control of behavior;
6. Mediated sharing behavior;
7. Mediation of individuation and psychological differentiation;
8. Mediation of goal seeking, goal setting, goal planning and achieving behavior;
9. Mediation of challenge: The search for novelty and complexity;
10. Mediation of an awareness of human being as a changing entity;
11. Mediation of an optimistic alternative" (Feuerstein, 1988:61).

Each of the above characteristics will now be discussed in detail.

3.8.2.1 Intentionality and reciprocity

Intentionality and reciprocity refer to the deliberate act by the mediator of positioning himself between the stimuli and the learner/child with the purpose of aligning and modifying the learning objects to make learning more meaningful to the student (Kozulin & Presseisen, 1995). Also, the mediator makes it explicit that the stimuli are not the sole purpose of the mediation process, but modifying the thinking processes of the learner. In other words, the mediator ensures that the student/child focus his/her attention on the learning object and extracts that information that is conducive to learning by seeing, hearing or experiencing those characteristics the mediator envisioned him/her to experience (Feuerstein, 1988). In other words, before mediation even starts, the mediator has a specific goal in mind and plans the learning activities in such a way to reach this aim. On the other hand, reciprocity is achieved when the individual response in a way that indicates that active learning has taken place as well as shows how conscious the mediator has become in the learners' response (Todor, 2013).

3.8.2.2 Transcendence

Transcendence within the theory of MLE occurs when a learning experience become apparent within a current setting and is transferred to different contexts. To illustrate the definition of transcendence, I will present an example of my experience as a father. As I arrived home one day, my son (aged four at the time) was playing with a fire lighter. My immediate reaction was to remove it from his hands and to tell him not to play with it anymore, never. This message to him had direct implications. The warning was only applicable to the current situation. In other words, the warning to him was that the current situation doesn't present any danger to him. Using transcendence within the theory of MLE I had to provide the reason why it is dangerous to play with fire so that he would use those reasons and transferred it to any other situation where the fire is concerned. I had to tell him why it is dangerous to play with fire, when it is suitable to use a firelighter and how to use it. What should he keep in mind when using a fire lighter i.e. wind, water, paper, etc. So, the reason not only applies to the immediate need but for future situations as well. On the other hand, an indication that transcendence has occurred is that my son can generalize the underlying principles to other learning situations (Todor, 2013).

3.8.2.3 Mediation of Meaning

Modifying and aligning learning objects or stimuli to make learning more understandable to learners might lose its value if the mediation has no meaning to the learners. Referring to my experience (3.4.2.2) telling my son No! with facial expressions and hand gestures presents a message with meaning and immediately my son experienced my feelings towards playing with fire. In other words, my mediation between the fire and my son becomes meaningful when I displayed my concerns towards the fire. The message that should be communicated is that because of my love/affection for my son, intervening between him and the fire provides a motivation for me as the mediator and also prevents him from denying the mediation that took place (Feuerstein, 1988). In other words, the mediation was meaningful for both my son and me, and it acts as a motivation for learning to occur.

3.8.2.4 Mediation of feeling of confidence

Mediation of confidence takes place when the teacher (mediator) assists learners in effectively participating in tasks through the development of their self-confidence. More precisely, the mediator's aim is to empower students so that they can become autonomous in their metacognitive processes as well as become more competent in their actions. Important to note is that competence in their actions isn't a once off process but occurs over time and develops through experience (Seng, 1997, Tzurriel, 2013). However, our education system, more specifically, schools lend themselves more to fostering competition amongst learners i.e. top 20 of the school, 100% pass rate and 20 A-aggregates. Moreover, adopting this competitive and a means to an end point of view often result in focusing more on errors learners make and not as much as the learning path of the students. Zooming in on learners' mistakes might lead to students concentrating more on their weaknesses than on their strengths.

3.8.2.5 Mediated regulation and control of behavior

This type of mediation occurs when the mediator provides space for students to become aware of self-reflection and adjusting their actions accordingly. This kind of intervention is extremely

useful because it motivates students to not only take control of their learning but also encourages them to make responsible choices for their actions (Tzuriel, 2013). Moreover, it also drives them to analyse each situation before acting.

3.8.2.6 Mediated sharing behavior

Mediation of sharing behavior revolves around co-operation between mediator and learners. In other words, opportunities are being created to share mutual ideas and beliefs. On the other hand, it also fosters communication skills i.e. listening to others and respecting others' point of views. However, the whole process is only possible if there exists mutual trust.

3.8.2.7 Mediation of individuation and psychological differentiation

Every learner is distinctive and different from each other. The mediator should nurture this uniqueness and differences amongst each other. So, on the one hand, the mediator fosters the acknowledgment of each learners' unique qualities and differences and on the other hand, he/she promotes the development of students' personal independence.

3.8.2.8 Mediation of goal seeking, goal setting, goal planning and achieving behavior

This process involves the mediator directing students in goal setting, goal planning as well as achieving their goals. The method of directing the students should include focusing students' attention on setting achievable and desirable goals. Also, students must believe that they can achieve these aims. In other words, it should be goals the pupils set for themselves and not someone else's goals.

3.8.2.9 Mediation of challenge: The search for novelty and complexity

Learners should be determined and enthusiastic to complete tasks whether simple or complex. The mediator's job is thus to create opportunities for students to engage in challenging tasks and

to keep at it until they achieve success. Moreover, students should become aware that difficult tasks require determination and with perseverance, they can overcome their fear for new, unknown experiences.

3.8.2.10 Mediation of an awareness of human being as a changing entity

Learners should become aware that they are a changing entity. The mediator should create opportunities for students to become aware of the changes that occur within them and how valuable these changes are for their success.

As seen from the above description of MLE, every individual can progress with sufficient mediation and become an effective learner and that his/her cognitive development can increase with the use of MLE. Moreover, effective MLE will increase purposeful learning and thinking and will give rise to modified cognitive structures and can lead to an increase in skills and competencies.

The next section focuses on computer mediated learning.

3.9 Computer-mediated learning environments

As stated in earlier chapters, Deaf and H/H learners make use of different modes of communication i.e. sign language, gestures, actions, body movements and position and facial expressions. Accordingly, it can be argued that these ways of communication guide their teaching and learning processes. In other words, Deaf and H/H learners have to use these modes of communication to make sense of what is happening in the classroom and demonstrate what they have learned in writing. Jewitt (2004) asserts that when computers are utilized in classrooms, learners have to assemble information from the mode displayed via the computer. Jewitt's argument is supported by research conducted by herself (Jewitt, 2003) on the use of mediated learning in the form of CD-ROMs in the literature classroom. On the one hand, she found that computer-mediated learning in the form of CD-ROMs reduced the imaginative constraints written text demands of learners. On the contrary, the multimodal features of CD-

ROMs reshaped the literature curriculum in some mode students could appreciate the characters in the written text and hence unlocked the curriculum to them.

Improvements in computer and network infrastructures have laid the foundation for more advanced online learning environments. This phenomenon has not only led to an increase in eLearning practices but also a decrease in face to face classroom practices (Graham & Misanchuk, 2005). A computer mediated learning environment (CMLE) is a platform that uses computer technology as a means to administer the teaching and learning practices. These conditions include “computer mediated communication, computer support collaborative work and distributed software environments” (Jonassen, Davidson, Collins, Campbell & Haag, 1995:15). Winer, Deighton, Gupta, Johnson, Mellers, Morwitz, O'guinn, Rangaswamy and Sawyer (1997) argue that computer mediated learning environments are links between the “sponsor” and the “user” and involves i.e. “information technology, feedback and customization” (p.288). In other words, these researchers are of the view that CMLE as an intervention strategy which provides information specific to a change in behavior before the intervention and afterward.

Graham and Misanchuk (2005) did a comprehensive study on computer mediated learning groups. They found that when cooperative learning, collaboration, and learner motivation underpinned this computer mediated learning groups, learners were in a position to negotiate meaning by disputing others’ ideas and maintaining their own. Furthermore, cooperative learning within this computer mediated learning groups resulted in an increase in academic scores as well as higher retention rates amongst learners within these groups (Panitz, 1999). However, Graham and Misanchuk (2005) did find two concerns about computer mediated learning groups which include the size of each group, the typography of these groups as well as the learning material.

According to Uribe, Klein, and Sullivan (2003), there is an increase in the performance of individuals who utilizes computer mediated collaborative learning environments than people who try to solve problems on their own. These researchers investigated the effects of computer mediated collaborative learning environments on the performance of university students while tackling problem solving tasks. Findings indicate an increase in interactions with computer mediated environments as to face to face situations. Furthermore, they found that the experiential group spends more time on the problem solving activities than the individual group.

Moreover, both groups experienced positive beliefs and feelings towards working collaboratively (Uribe, Klein & Sullivan, 2003). Although these findings are based on university students, it still provides useful information for the current study.

Ping and Swe (2004) on the other hand argue that it is crucial when learners are presented with computer mediated lessons, sufficient scaffolding techniques should underscore it. They further posit that scaffolding techniques in computer mediated environments can enhance learning. However, teachers should guard against poorly constructed scaffolding activities as this will not only demotivate learners but also shift the focus from authentic learning.

The question that comes to mind is how is this possible? How can the use of computers mediate the learning process and of what affordance are computers to mathematics teaching and learning? To answer these questions one should first adopt a perspective of how technology is viewed. This research study adopts a view of computers and computer environments as “cognitive technologies” proposed by Pea (1987:91). A cognitive technology, according to Pea (1987), is any tool that can reduce the cognitive load of the mind. In other words, a medium that can assist in exceeding what the human mind is capable of, relating to limited thinking and learning processes.

Tools that are classified as cognitive technologies include: “all symbol systems, including writing systems, logics, mathematical notation systems, models, theories, film and other pictorial media, symbolic computer languages and computer systems” (Pea, 1987:91). These tools were also referred to as extracortical organizers of thought since these devices coordinate thought processes outside the human mind (Vygotsky, 1978). Although Pea (1987) refers to these tools as cognitive technologies, others refer to it as *technologies of the mind* (Salomon, Perkins & Globerson, 1991), *mindtools* (Jonassen, Carr & Yueh, 1998) and *cognitive tools* (Jonassen, 1992). These researchers all agree that these *cognitive technologies* can assist students in the construction of knowledge.

Jonassen (1994) concurs with the view that computers and computer environments have the potential to support learners in knowledge development. According to this view, cognitive technology in the form of computers and computer environments, when provided to learners as a medium to extend their mind’s limitations with mathematical thinking processes, can help students in understanding mathematics (Jonassen, 1992). Therefore, utilizing these cognitive

tools can assist students in developing a knowledge base which in turn might provide opportunities for learners to interact with the content and they might also encounter a more meaningful learning process.

3.10 Summary

This chapter shed some light on how Deaf and H/H learners come to know mathematics and how the learning theories of constructivism, socio-constructivism, and MLE can assist them and teachers in the teaching and learning of mathematics with particular reference to mathematics assessment based on the function concept. Furthermore, the chapter also reviewed the use of computers within a mediated learning environment and how it can assist Deaf and H/H learners with difficulties they experience with Paper and Pencil Assessments. However, a point that needs to be considered is that many of the research specifically on computer mediated learning were done abroad either with university students or intermediate phase learners. Although positive evidence was presented in all the studies, it still isn't a guarantee that it will work in the current study. Also in countries abroad, legislation and policy are already in place to administer online mathematics assessment, while it is still being considered here in South Africa.

The next chapter focusses on online assessment with particular reference to online mathematics assessment.

CHAPTER 4: ONLINE MATHEMATICS ASSESSMENT FEATURING MOODLE AND WIRIS

4.1 Introduction

This chapter includes a review and discussion of online assessment, especially literature relating to online mathematics assessment unique to Deaf and H/H learners. Since the aim of this research study is to examine the use of OMA as an alternate assessment for Deaf and H/H students, I deemed it necessary to illuminate on how it will be administered. Firstly, I will be presenting a definition of OMA as well as the rationale for choosing this type of assessment. It is followed by the different perspectives on OMA and ethical considerations when deciding to use OMA as well as the characteristics of valid OMA. After that, it highlights theories relating to online mathematics assessment for Deaf and H/H learners. Finally, it includes the use of Moodle-based assessments, WIRIS as a plugin in Moodle, WIRIS CAS, and WIRIS quizzes to develop online mathematics assessments for Deaf and H/H learners.

4.2 Online Mathematics Assessment (OMA)

The following section provides a brief definition of OMA followed by the rationale behind the use of OMA. After that different views of OMA are discussed together with ethical consideration when deciding to use OMA. It is followed by online mathematics assessment specifically for Deaf and H/H learners. Since this research study utilizes Moodle and WIRIS quizzes, I deemed it necessary to conclude the chapter with a detailed description of Moodle assessments and WIRIS quizzes and how it will be used in the current research study.

4.2.1 Definitions

Online mathematics assessment is defined as mathematics assessment that is administered in an online learning environment. In contrast to the traditional PPA, OMA is done with the use of

computer network technologies, where the teacher creates online assessments, the computer captures the learners' answers, scores it and provides immediate feedback to students. Sangwin (2004) argues that online mathematics assessment uses computer algebra to assess student's answers over the internet.

4.2.2 Rationale behind the use of OMA

Traditional assessment practices entail the teacher creating a PPA and students completing the evaluation by either writing their answers on a piece of paper or marking a checklist with the correct answer. Afterward, it's handed in for marking and scoring which is done by the teacher. Taking into consideration class sizes and other administrative duties, this can be a time-consuming exercise. Moreover, mistakes made by learners can only be communicated to them after all the marking and scoring is done, which limits students from learning from mistakes made in the test and provides little room for self-reflection (Walker & Delius, 2004). Adding to Walker and Delius's argument, I would point out that providing learners with prompt feedback not only guarantees critically looking at their approach to the particular problem, but it also allows them to retrace their steps and to prevent them from making the same mistake again. As a result, the quick feedback can provide opportunities to rectify future errors and create space to learn from their mistakes.

Since online assessment features include immediate marking and scoring as well as immediate feedback on assessments, issues of delayed feedback and class sizes can be eliminated (Walker & Delius, 2004). Other features of online assessment specifically Moodle-based mathematics assessment will be discussed in detail further below.

Even more important, the cost of printing and copying might be cut in half when assessments are taken online. For example, I have a class of 20 Grade 9 learners. One mathematics assessment containing five pages adds up to 100 pages in total to copy as well as the amount of toner use (black ink). However, when the same assessment is developed online, no ink or paper is being used which reduces the cost of ink and paper. Although Sandene, Horkay, Bennett, Allen, Braswell, Kaplan and Oranje (2005) argue that online assessment development can be costly, from my experience it is the other way around. I believe that by creating a customized quiz

template which teachers can modify, the time and cost can also be cut in half. Additionally, it can work for a variety of question types which eliminates the burden of teachers creating each test from scratch.

I am also of the view that a transition from PPA to online assessment might not be as smooth as foreseen. Dynamics like, how to structure a test online, training of staff, security issues regarding test taking, access to tests, test storage and archiving as well as the administration of the tests should all be considered. Although Sandene et al. (2005) share this view, they posit that operational issues can hamper the transition from paper to paperless tests. They argue that training of administrators, recruiting the various schools as well as infrastructures and networking technologies are all concerns that could slow down the transition.

The next section describes the different perspectives on Online Mathematics Assessment.

4.2.3 Different views on OMA

Sangwin (2004) reported on the use of Assessment in Mathematics (AiM), a computer-based assessment system which is utilized by the Mathematics and Statistics Department at the University of Birmingham. He argues that computer-based quizzes have the potential to provide learners with immediate feedback, which is conducive to mathematics learning. Furthermore, he posits that the reporting feature of online quizzes highlights misconceptions students hold about topics in mathematics and provides a platform where these mistakes can be rectified.

A similar study conducted by Walker and Delius (2004) on the use of AiM at the University of York concluded impressive results. These researchers found that through the use of online mathematics assessment i.e. AiM, quizzes could be randomized, which means that since it uses a CAS to generate mathematical expressions, variables can be employed. The variables in each mathematical expression can be thus be changed and therefore each student can receive questions based on the same set of skills to perform. Accordingly, each student can practice a skill on a topic of mathematics by experiencing a wide variety of problems based on the same theme. Moreover, they posit that from the log files captured within the online mathematics system, teachers and students could gain valuable information regarding misconceptions, tryouts

on specific problems as well as the time spend on each mathematics problem (Walker and Delius, 2004; Sangwin, 2004).

Blanco, Estela, Ginovart, and Saà (2009) investigated the use of Moodle quizzes with 70 Civil Engineering first year students. The aim of their investigation was to evaluate these students' answers to see whether the questions posed within the quizzes were suitable. The results of the study conclude that Moodle quizzes have the potential of providing students with useful feedback regarding their learning paths. However, Kokol-Voljc (1999) suggests that educators should decide which questions are relevant to include in these quizzes. He further posits that online quizzes should adhere to two basic principles i.e. "Understanding the theoretical meaning of the mathematical concepts and using mathematical concepts in modeling real situations" (Kokol-Voljc, 1999:12).

On the other hand, Butcher (2008) reported on the Open Universities (OU) adoption of OpenMark, an online assessment system, integrated within Moodle. OpenMark was developed as the OU's online evaluation system which started out as a CD-ROM program and has since been developed as an online evaluation system. Currently, the OU uses online quizzes.

García, García, Del Rey, Rodríguez and De La Villa (2014) are of the view that a change in the methodology of teaching and assessing mathematics is inevitable. They believe that mathematics teaching and assessment, especially the use of CAS's for mathematics assessment, can enhance the evaluation of different facets of mathematics learning as well as "foster self-efficacy and promote a way of working closer to the real world" (Garcia et al., 2014:11). In other words, they believe that utilizing a CAS in mathematics assessments has the potential to enhance learners' academic scores as well as increase their mathematical competencies.

A comparative study (Moon, 2013) was conducted on the use of paper and pencil mathematics assessment and online mathematics assessment. The study examined learners in Grades 4, 8 and 11 in schools in Nebraska and in which way test modes i.e. pencil and paper or online, influenced these pupils' performance in mathematics. Although the research results indicate no significant difference between the two methods, other variables like student characteristics, school attributes, and test accommodation need to be taken into consideration and not just the style of testing. Moreover, the study only focused on the post-test within a quasi-experimental design which further limits the study to be generalizable. In my view, this study should have

concentrated on the differences between group performances peculiar to a particular stage and not just the performance within modes of test administration. In other words, the item difference for either pencil and paper or online mathematics assessment should be looked at which might have rendered proof of equivalence or not.

Pitcher, Goldfinch, and Beevers (2002) investigated the use of Mathwise, a multimedia system. This system consists of modules covering mathematics and science activities and assessment. The Mathwise multimedia system includes a question bank, which has the potential to be randomized, formative as well as summative assessments, depending on the need, has instant marking, scoring, and feedback features and facilitates question chunking, where learners can get partial marks for correct steps. These researchers found that students preferred the use of online assessments more than paper and pencil assessments. The reasons for this include the following i.e. 1) they could practice tests before taking the initial test, 2) they had more opportunities to change their answers before submitting it for scoring and 3) the value of the immediate feedback they got after the test was taken. They also found that the frequency of using Mathwise influenced the performance in the overall scores of the test. The study concluded that online assessments “provide valid assessment procedures and is comparable to pen and paper variety” (Pitcher et al., 2002:172).

Although I share in the argument of immediate feedback, I still maintain that some of the learners don't realize the value of feedback on tests. Also, most of the time the feedback is the correct answer and not a breakdown of how the solution was obtained. Moreover, from my experience, written feedback also presents an obstacle, especially when written text is a barrier, like in the case of Deaf and H/H learner. A solution which worked in my class was to present students with a screencast of similar examples. A screencast is a digital recording of your computer, iPad or Tab screen, which can be played back. In other words, making use of screen capturing software, it captures handwriting and mouse movements and provides a video output of the actions done on the screen. Learners can thus follow the screencast and within the steps, they could see where they made a mistake. Although this approach is time-consuming, the results are worth the effort. Ramos, Trenas, Gutiérrez and Romero (2013) support my argument. They claim that when they incorporated an E-Assessment module within Moodle, which automatically verifies the assignments of engineering students, teachers had more time to attend to problem

areas within the topic, the learners were more motivated because of the frequently updated assignments as well as the immediate feedback they received.

Stacey (2003) has a different view and claims that online mathematics assessment, specifically those utilizing CAS, yield a new approach to question formulation as well as marking schemes. Although this is a valid argument, I still maintain that with thorough planning and administration, possible successes can be achieved by learners utilizing online assessments. However, problems can arise when students aren't familiar with a CAS, or a different CAS is used as the one they are familiar with. So, the fact that the use of a CAS can be challenging has its grounds.

The next section focuses on ethical consideration when deciding to use online assessments.

4.3 Ethical considerations of online assessment

This section sheds light on ethical considerations of online assessment. Not only does it provide suggestions to ensure that concerns with ethics are dealt with but it also presents possible solutions to how the reliability and the validity of online assessment can be maintained.

Although online mathematics assessment sounds promising and although it can reduce time spent on marking and scoring of assessments, other factors need to be taken into consideration. One such factor is cheating. McMurtry (2001:1) refers to it as “e-cheating”. He defines e-cheating as a means to obtain answers to exam/assessment questions while or before the actual test is taken. Olt (2002) on the other hand claims that e-cheating occurs when learners exchange emails without the teacher noticing. Furthermore, he asserts that students are provided certain roles, especially in VLEs, where they can download the assessment beforehand, obtain the answers, distribute it to other learners and then complete the test as if it was the first attempt to the test. According to the above views, it seems like e-cheating is inevitable, hard to detect and nothing can be done about it.

Eplion and Keefe (2010) posit that cheating can be prevented by establishing some security protocols. These researchers provide a set of measures to ensure that cheating in online assessments is eliminated. These actions include:

4.3.1 Protect access to the test/exam

The test is only accessible at a particular time and date and cannot be accessed by students beforehand. This measure guarantees the security of the test. Furthermore, VLEs provide log information on when users accessed the test and when they submitted the test, which further strengthens the security (Eplion and Keefe, 2010).

4.3.2 Track interaction

This feature is standard in most VLEs and involves the online system tracking each students' movements within the VLE. It provides a detailed report on all the activities learners accessed from the start of the test to the finish. It also denies students access to the test or exam after the specific timeframe or deadline. Moreover, a detailed log file is kept on the actual time the learners spend on one question and the exam. Accordingly, time for each item can be set and automatically submitted when the time have passed (Eplion and Keefe, 2010).

4.3.3 Randomization of questions

Another possible measure that can be put in place to eliminate cheating in online assessment is through randomizing the test questions. In other words, the test/exam is constructed out of a pool of questions. Each student receives a different question from the pool and the possibility of two students working on the same problem at one time is limited (Eplion & Keefe, 2010).

Although I support their argument on the use of randomization, my view slightly differs. From my experience with the randomization of mathematics quizzes, learners complain that some of them got the easy questions while others got the most difficult ones. Therefore, randomizing the test items for me was a major concern since it not only influences the learners' test scores but it also demotivates other students from taking the test.

Marais, Argles and von Solms (2006) suggest that certain principles should be put in place to guarantee a fair and valid test and to ensure the trustworthiness of the test. Their proposed framework includes:

- Authenticating the student taking the exam/test using passwords or secure login information;
- Make use of controlled environment to administer the test;
- Using randomization of quiz items in the LMS;
- Denying learners, the opportunity to log in twice, which might result in double test submission and will compromise the integrity of the test;
- Secure the privacy and confidentiality of each students' response and results;
- Make use of protocols to eliminate opportunities for students to deny their submissions.

Lorenzetti (2010) posits that one way to secure tests/exams is through the utilization of an Online Proctor System (OLP). The OLP analysis students' keyboard strokes and can determine whether it was, in fact, the same student taking the whole test. In other words, the system evaluates each users' keystrokes, compiles a profile of the user based on these keystrokes and analyze the keystrokes throughout the test comparing it to the profile compiled by the system. Additionally, the system prevents learners from accessing features outside the VLE and simultaneous pressing of certain keys like alt, control and delete are disabled which prevents students from exiting the VLE. Although Lorenzetti advocates the success of this system to reduce and possibly eliminate e-cheating, it is high-priced, and students have to spend an enormous amount of time learning the system, before attempting to utilize the system. Another drawback is the bandwidth speed. For the OLP to work optimally, it needs high-speed internet service which excludes students from places with low bandwidths.

4.4 Validity

Validity refers to the collection of evidence in support of the inferences being made on how learners performed in a particular assessment (Moskal & Leydens, 2000). In other words, was the conclusions drawn from the test results useful and meaningful? Therefore, a valid assessment sets out to measure what it was designed to measure (Dunn, Morgan, O'Reilly & Parry, 2003).

Validity also refers to the assessment instrument measuring what it was intended to measure (Davis, 1999). For example, Mathematics word problems should not be an obstacle due to learners' reading abilities, since reading skills won't be tested but mathematics word problem-

solving. Thus, when students obtain incorrect answers, an invalid inference can be drawn by the teacher that the student has not mastered mathematics problem solving skills and didn't give any attention to the reading difficulties the learner experienced while tackling the question.

Moreover, it also measures whether the assessment addresses the content domain. In other words, testing learners' addition, subtraction, multiplication and division skills should include questions about an equal weight of all the operations.

4.5 Reliability

Reliability denotes the level to which a test instrument produces a consistent result each time it is administered (Moskal & Leydens, 2000). In other words, when your colleague conduct a test provided by you, will they obtain the same results you have achieved? Moreover, when your peers review your assessment task, will they conclude that the assessment is fair and reasonable in its aim to assess the performance of learners (Dunn, Morgan, O'Reilly & Parry, 2003)? The question that should be asked is whether online mathematics assessment will produce reliable results.

Davis (1999) asserts that a test's reliability can be guaranteed when the test administrators consider the following:

- Use questions that do not mislead students;
- Questions should not be ill-defined (clear directions should be given);
- Use scoring criteria that are clear and distinct;
- Test questions should be a representation of the course work covered;

It is thus important for test administrators to spend adequate time on test preparation i.e. designing and developing tests. Furthermore, teachers should make sure that the test evaluates what is done in class and that the questions within the tests are unambiguous.

4.6 Online assessment for Deaf and H/H learners

Peltenburg, Van Den Heuvel-Panhuizen and Doig argue that CBAs can provide students with disabilities a “structured, stylized assessment environment in which they can easily keep track of their actions” (2009:276). For example, teachers and learners have easy access to past assessment results, wrong answers as well as immediate feedback on answers. Moreover, students can practice tests, redo assignments based on feedback and learn through randomized questions. Teachers, on the other hand, can quickly identify problem areas and implement intervention strategies. This argument is strengthened by Woodward & Rieth, who argue that an “ICT environment can register detailed information on pupils’ strategies, and so provide a vehicle for orchestrating higher quality assessment” (1997:517–521). These researchers all agree that an ICT environment can provide teachers with more insight of learners thinking processes since it can provide a more detailed account of the strategies students use in contrast to PPAs.

The Malaysia Examination Board conducted another research finding that proved promising results (Malaysian Ministry of Education, 2004). Their findings confirmed that the performance of deaf and H/H learners in Interactive Computer-based Assessment, SIBKOM, were higher than those groups that made use of live interpretation. Similarly, the National University of Malaysia, Malaysian Examination Board (2008), developed the E – Voice Alternative Assessment, for learners with special needs which also proved to improve the performance of Deaf students.

Yasin, Sahari, and Nasution (2013) developed an internet based Literacy and Mathematics assessment prototype (iLiMA) for the Malaysian Ministry of Education. The prototype consisted of sign language videos which translated written language and mathematics assessments. These researchers concluded that with the assistance of this iLiMA prototype, Deaf and H/H students could gain access to language and mathematics assessments and non-biased inferences could be drawn from the results.

Reitsma (2008) discovered in his study that computer-based exercises assisted Deaf and H/H learners to be successful in reading. Similarly, Loeterman, Paul, and Donahue (2002) designed the “Cornerstones Approach” which is a multimedia curriculum specifically for Deaf and H/H

learners. They are of the view that such an approach would guide Deaf and H/H students in words construction and comprehension. In line with these studies were research conducted by Mueller and Hurtig (2010) who developed an eBook with video signers. They conclude that the Signing eBook led to an increased time spend utilizing these eBooks for reading as well as an increased attainment in vocabulary.

Evidence based on my research while doing my master's thesis highlights the strengths of using online quizzes in my mathematics classroom (Damon, 2015). Not only did Deaf and H/H learners find it easier to do online quizzes as to PPA but the inclusion of a Glossary within these quizzes made it possible to have immediate access to difficult words and phrases. Moreover, the immediate feedback provided them with extra assistance in grasping mathematics concepts and helped them in their construction of mathematics knowledge. Furthermore, the multi-representation of mathematics content within the quizzes provided learners with opportunities to translate between representations in mathematics which further strengthened mathematics learning. These findings are also in line with Pliskhin (2011) who asserts that computer-based assessment can be used as an assessment accommodation and has the potential to assist learners with learning disabilities. He further posits that computer-based tests can be structured according to individual needs which further strengthens its potential to elevate test scores.

Although standalone quizzes can assist learners with the teaching and learning process, it is more useful within an LMS. Since my learners and I are familiar with learning management systems, especially Moodle, we opted to use it within the current research project. Moodle was developed to assist educators in creating quality courses. Furthermore, Moodle is underpinned by the pedagogical principles of social constructivism which envision that every participant is a teacher as well as a learner (Pan & Bonk, 2007; Dougiamas & Taylor, 2003; Moodle, 2016). Moreover, instructors in Moodle can facilitate activities, assignments, quizzes, discussions, etc. to provide learners opportunities to participate in these modules (Pan *et al.*, 2007; Moodle, 2016). In other words, not only does Moodle assist teacher and learners with their learning processes, but it also creates space for collaboration and support (Moodle, 2016). From my experience, while using Moodle, I have discovered that it has the potential to reduce reading barriers, paper and pencil assessments present, by integrating some modules. For example, using the Glossary module in

conjunction with the quiz module provides learners with the signed vocabulary of difficult words. The Deaf and H/H students appreciated this feature since it not only allowed them to understand difficult words, but it provided them with some context of the mathematics problem which further assisted them in understanding the problem. Moreover, since interactive content can easily be integrated within Moodle, it can support Deaf and H/H learners with understanding abstract mathematics content (Damon, 2015).

For this reason, I have decided to pursue this study to examine the use of online mathematics assessment as an alternative to PPA. The next section describes Moodle and the modules that are utilized in the current research study.

4.7 Moodle

Moodle is the acronym for Modular Object Orientated Dynamic Learning Environment (Dougiamas, 2001; Cole & Foster, 2007; Moodle, 2016). It is also referred to as a Content Management System (CMS) or a Learning Management System (LMS). All in all, it is an online learning environment where content can be created, stored, tracked, accessed, co-constructed and assessed in a collaborative manner (Itmazi & Megias, 2008). Furthermore, it also means that Moodle consists of tools that can be easily accessed to create an online learning experience.

Three categories of LMSs exists. These include Open Source, Cloud, and Proprietary Learning Management Systems. The difference between these three is that Cloud and Proprietary LMSs are license-based which means that each year the software license needs to be renewed by paying an annual fee. On the other hand, Open Source software, like Moodle, requires no annual license fees to be paid, and the source code of the software is freely available to a community of developers which means that these developers can use it to either develop new themes or plugins for Moodle (Moodle, 2015). In other words, any user can freely download Moodle, install it either on their server or standalone personal computer and run it from there. Furthermore, since there is a community of developers, the support needed is within reach to everyone.

A further distinction between Moodle and other LMS's is the availability of its tools. Moodle is installed with a default set of instruments which can be used to construct courses on any topic. In contrast to other LMSs which showcase its tools as part of their interface, Moodle tools are part of the architecture of the software (Cole & Foster, 2007). In essence, this means that users can construct their courses making use of the tools. Additionally, it also means that Moodle isn't just limited to uploading static content, but with the utilization of the tools in Moodle interactive content can be constructed, collaborative activities can be engaged in, and ideas can be shared (Cole & Foster, 2007; Damon, 2015).

Moodle is also very flexible and versatile. I have discovered these characteristics from my experience with Moodle. For example, Moodle consists of 5 static course tools i.e. text page, web page, web links, view course directories, and labels. These are referred to as static course material since students aren't able to interact with these elements, only read instructions or messages from it. Furthermore, it also consists of six formats of interactive course items i.e. assignments, choice modules, journaling, lesson module, quiz module and a survey module. These are referred to as interactive course modules since learners can interact with courses created with these modules. Additionally, Moodle also includes five modules in which students can interact with each other or with the teacher. These include the chat, wiki, forum, glossary and workshop module (Rice, 2011). From my experience, other LMSs provide users with online courses which for me presupposes that learning is a linear process while Moodle does quite the opposite by providing users with an online learning experience. According to this view, online courses are presented as images, text and sometimes multimedia content which users must extract information from, one after the other. On the other hand, online learning experience consists of scaffolding mechanisms, adaptive content, and randomized items which can be adjusted according to each users' needs (Rice, 2011).

Currently, Moodle is being used by schools, universities, government departments, private companies, etc. There are to date 63,013 registered Moodle sites which are spread over 222 countries (Moodle, 2015). Moreover, 8,615,421 courses have been constructed using Moodle and the user's amounts to 78,068,207 with enrolments of up to 205,778,043.

The architecture of Moodle is underpinned by the philosophy of Social Constructivism. Essentially, this means that the Moodle environment presents opportunities for learners to organize and link ideas of existing knowledge and new found knowledge through their interaction with others. In other words, while interacting with the teacher or other learners within the learning environment, they may become aware of other students' perceptions on topics and have a choice to abandon their views and adopt the new views or hold on to their perceptions and influence others' views. This view is also in line with Khairiree's (2010) research findings on the use of Moodle and Geometer's Sketchpad. Not only does he acknowledge the potential of Moodle and Geometer's Sketchpad to create opportunities for learners to construct their mathematical knowledge but he also argues that with the use of Moodle, an increase of students' conceptual knowledge was noticeable. On the other hand, Martin-Blas and Serrano-Fernandez (2009) claims that the use of Moodle increases the test scores of their physics students and the interactive content motivated learners more than pencil and paper exercises.

However, contradicting results were found in a study conducted by Alves, Viegas, Marques, Costa-Lobo, Silva, Formanski, and Silva (2013). Not only did these researchers find that students were more enthusiastic about static content i.e. lecture notes, hard copies of course material, but they discovered that low interest was illustrated within the interactive modules like the quiz and online reports. Although these researchers conclude that some external factors might have influenced the low motivation on the use of Moodle, it is still a venue worth examining.

4.7.1 Moodle-based activities

Different types of Moodle-based activities exist. These include Assignments, Databases, Workshops, Quizzes, SCORMS, and Books. All of these activities can be used as an assessment type and therefore be graded. Since this research study only makes use of two types of activities i.e. Assignments and Quizzes, only these two will be discussed in detail.

4.7.1.1 Moodle Assignments

An Assignment in Moodle constitutes the same as a paper and pencil task; the only difference is that learners can do it offline and afterward submit it via a file upload option, or they can do it online and submit it when they are done (Cole & Foster, 2007). Currently, there exist four assignment types.

Uploading a single file, where learners have the option to upload only one file in any format. In other words, students can be asked to upload a Microsoft Word, Excel, or PowerPoint document or a photo, image, video or sound file. These records are assessed by the teacher and graded accordingly.

Offline assignments entail assignments done through pencil and paper exercises. In other words, learners can see the instruction of what they need to do, within Moodle, but they won't be able to upload anything since the activity needs to be done remotely (not within Moodle).

The online text provides learners with a space to input text to do the activity and a button to submit the activity for online grading. In other words, students don't need an external program like a text editor, to type their assignment, they are provided with a text editor in Moodle and only need to prepare their document in Moodle and then submit it via a button.

Advanced file uploading allows learners to upload more than one file. These records can include text documents, slides, video files, sound files, images or a file in any other format. The teacher can reduce the file size learners can upload by selecting from a list of file size option.

Each of these Assignment types allows teachers to set default settings which include defining the due date of the assignment, the date when the task becomes available or whether teachers want to be notified when learners have submitted their assignment and which tasks need grading. Also, within these Assignment types, space is provided for teachers to add comments, suggestions and even highlight mistakes made by learners. Moreover, space is also provided for students to add comments on their assignments (Cole & Foster, 2007). The next section focusses on Moodle quizzes.

4.7.2 Moodle Quizzes

For teachers to grasp what is going on in the minds of learners, they need to assess continually students' progress on what the student knows and don't know. Moodle quizzes can be used to determine whether students have mastered the content knowledge and can apply it in certain situations (Cole & Foster, 2007). Information obtained from these quizzes can provide teachers with useful data on learners' performance. Also, feedback from students' interaction with the quizzes can guide teachers in adjusting the units of learning of the learners.

Quizzes are one of the most used modules in Moodle because of its flexibility (Cole & Foster, 2007). It allows educators to create quizzes from an array of question types. Moreover, the questions are stored in a question bank which can be reused as many times as you need to. Additionally, quizzes can be set up to provide learners with an opportunity to take the test as many times as the option allows them. Furthermore, grading of quizzes are done automatically, and educators can choose whether to provide immediate feedback or not (Cole & Foster, 2007).

Moodle quizzes can be used for:

- Exams preparation
- Continuous assessments
- For feedback purposes
- Measure learners' understanding of content knowledge
- For self-assessment purposes

4.7.2.1 Moodle question types

The different question types within the quiz module include: calculated, calculated multi-choice, calculated simple, cloze questions, essay, multiple choice, matching, short answers, true or false and description questions. Since only calculated, numerical, cloze and short answer questions will be used in this research study; only these will be discussed next.

4.7.2.2 Calculated questions

These question types use mathematical equations which include variables and extracts data from a database when learners take the quiz. In other words, variables are placeholders for number sets and can, therefore, randomize each question which means that every time the student takes the quiz, the values change. These randomization features are also useful security measures and decrease possible cheating from learners.

4.7.2.3 Numerical questions

These question types accept only numerical short answers. In other words, students only need to type in a numerical answer for these type of questions.

4.7.2.4 Cloze questions

The cloze question type includes multiple choice, short answer, and numerical questions. The answers are embedded within these question types. It means that a formula is written within the question, which provides a space for learners to type their answer in. Moodle measures the students answer against the formula and grades it accordingly. For example, for multiple choice questions the following formula is used: `[[1: multiresponse: v]]`, for numerical questions: `[[2: numeric: _10_]]` and for short answer: `[[3: pmatch]]`.

4.7.2.5 Short Answer questions

These question types provide learners with a space to type their answers. However, the teacher provides a set of the acceptable answer, and the pupils' answers are graded accordingly. In other words, the students' response should match the acceptable answer for them to get it right.

Other question types can be installed as plugins in Moodle, which adds to Moodle's functionality. These plugins will now be discussed, especially those that will be used in this research study.

4.7.3 Plugins in Moodle

Moodle is an open source software package, which means that the scripting code Moodle is built on, is freely available to all developers. It also means that developers can use the source code of Moodle and design plugins that are compatible with Moodle and can be installed within the LMS (Moodle, 2015). However, modifications to the source code of Moodle should be in line with the GNU General Public License. Currently, an array of plugins exists and are being developed daily with each version of Moodle. The plugin that this research study makes use of is the WIRIS CAS, WIRIS editor, and WIRIS quizzes.

4.7.4 Mathematical notations

For Moodle to display mathematics correctly, it needs a TeX notation filter. The TeX notation filter allows Moodle to display mathematics notations as images (Wild, 2009). In other words, the TeX filter recognizes mathematics text you type in the Moodle, text editor. When it finds the mathematics notations, it's converted to images. For example, the Algebra filter looks something like this:

@ @ 1/2+1/3=5/6 @ @ and will display like this $\frac{1}{2} + \frac{1}{3} = \frac{5}{6}$

Another filter that can be used is the MathJax filter. This filter is different from the TeX filter since it uses its equation editor where users can select from a variety of operators to input mathematics notations. When the MathJax editor is activated, it displays the following menu where users can create mathematics expressions and equations.



Figure 4.1: MathJax equation editor in Moodle

The third filter type is the Algebra filter. This filter displays mathematics in a Graphics Interchange Format (GIF). In other words, the Algebra filter searches for mathematics within the HTML document and converts the mathematics into a GIF image which displays the mathematics equation or expression (Moodle, 2015).

All three filter types are very complicated to use, and a sound knowledge of the different filter types is needed. Furthermore, these filters act differently in different browsers, and there is no guarantee that the mathematics expression will display correctly. Moreover, if an incorrectly converted image is displayed, it can negatively influence the learners' answer to the question and as a result, invalid inferences can be drawn from their assessment scores.

There are, however, solutions to these problems. One such a solution is WIRIS, which will be discussed in detail below.

4.8 WIRIS

WIRIS is an internet-based platform which can be utilized to execute complex mathematics operations. It consists of WIRIS Editor, WIRIS Computer Algebra System (CAS), WIRIS Quizzes and WIRIS Plugins. Each of these will be discussed below.

4.8.1 WIRIS CAS

WIRIS CAS is a computer algebra system (CAS) which also includes a Dynamic Geometry System (DGS) (Xambó, Eixarch & Marquès, D, 2002). It is an online mathematics system designed specifically for education from primary to university level. It consists of an array of applications ranging from operations, symbols, analysis, matrix, units, and geometry. Moreover, WIRIS CAS deals with all mathematical themes including Calculus, Algebra, Geometry, Differential Equations, Arithmetic, Functions, Mathematical objects, Statistics, etc. Additionally, WIRIS CAS also has an offline version namely WIRIS Desktop, which can be installed on a standalone computer.

4.8.2 WIRIS Editor

The WIRIS editor is a “*what you see is what you get*” editor, also referred to as an equation editor (WIRIS, 2015). Since the editor is JAVA-based, it can run in all the browsers, and it can represent mathematics in different formats including LaTeX, PNG, Flash, JAVA, etc. The WIRIS editor comprises of 2 main elements i.e. the JAVA editor and the web services. While the JAVA editor includes a mathematics toolbar where users can select from an array of mathematical objects to display, the web service captures users’ mathematics input through the mouse or keyboard and converts the LaTeX symbols into mathematics images.

4.8.3 WIRIS Quizzes

WIRIS quizzes improve online mathematics and science quizzes by adding more functionality and interactivity to the quizzes (WIRIS, 2015). It includes 6 question types i.e.

- *Cloze questions* allow the teacher to embed parts of the answer within the question statement.
- *True/False questions* allow users to select the correct response to the question.
- *Matching questions* allow users to make connections between the various elements.

- *Multiple choice questions* provide learners option from which they can choose. The students must select from a range of options which are the correct ones.
- *Short answers* require learners to insert their answers within a given textbox.
- *Essay questions* require learners to provide their answer/s within a given textbox.

The question types used in the current research study includes cloze, true/false, matching, multiple choice and short answer questions.

These items are enhanced in the following ways:

- “the quizzes make use of the WIRIS editor which provides a toolbar for inserting formulas and displaying these formulas within any web page
- the formulas are being validated in real time and checked for consistency
- answers are being graded whether they are in line with the predetermined response provided
- randomization of questions can be used by using variables
- the learners use the formula editor to insert their answers
- each question type includes an embedded WIRIS editor which students can use to create their answers
- 2D and 3D mathematics objects can easily be integrated within questions” (WIRIS, 2015).

4.8.4 WIRIS Plugin

The WIRIS plugin integrates the WIRIS CAS and the WIRIS editor within different LMS. The plugin is compatible with the following LMSs: Moodle, Sakai, Joomla and WordPress (WIRIS, 2015). Essentially, this means that the plugin should be installed on the web server where the LMS resides and accessed within the HTML (Hypertext Markup Language) editor of the LMS.

4.8.5 Research on the use of WIRIS

Estela, Saa, and Villalonga (2009) assert that the use of WIRIS quizzes for continuous assessment with university students in the engineering department enhanced their mathematics learning. On the one hand, these researchers found the scores of the students improved and on the other hand, the participation within these courses stabilized. Moreover, the number of students failing these courses dramatically decreased.

A similar study performed by Calm, Ripoll, Masià, Sancho-Vinuesa, Olivé, Parés, and Pozo, (2012) rendered positive results. These researchers examined the use of WIRIS quizzes as a continuous assessment tool by 65 university students in the mathematical analysis class. On the one hand, they found an increase in the continuous assessment scores of these students as well as fewer dropouts in the overall course. On the contrary, they also found a reduction in the number of students failing these type of assessments. Moreover, they experienced a positive behavior of students towards these type of assessments while utilizing WIRIS quizzes (Calm et al., 2012).

Vinuesa and Masià (2007) on the other hand, however, discovered somewhat controversial evidence on research done with engineering students. They examined the use of virtual learning environments and WIRIS to prepare students for a mathematics course enclosed in the engineering curriculum. They found that the students' interaction didn't have any negative or positive effect on the students' performance in mathematics. However, these students were better groomed for the engineering course. They conclude their study by providing some guidelines which one should consider which include:

- improvements to the user interface i.e. better-structured course content and making use of more interactive content, video, and images
- enhancing discussions on course material between teachers and students and providing space for students to pose comments, concerns as well as seek help
- more importantly including an assessment tool which can enhance learners' mastering of course objectives as well as a grade book feature where results can be analyzed for improvement purposes

Huertas (2007) adds to the above argument by highlighting the importance of pedagogical principles underpinning any online learning by students. In her study examining the experience

of university students in a virtual learning environment making use of WIRIS to represent mathematics, she reported positive results. However, not only did she shed light on WIRIS as a useful representational tool for mathematics but she also encourages the use of alternate assessment measures through the use of new technologies such as computer algebra systems like WIRIS.

Bogarrra, Corbalan Fuertes, Font Piera, Plaza Garcia and Solsona (2012) on the other hand argue that WIRIS quizzes added additional functionality to Moodle. These researchers did a comprehensive study on the integration of WIRIS quizzes in the electrical engineering class. Their findings indicate that the WIRIS calculator decreased an enormous amount of time students had to spend on mathematical operations and also improved the students' assimilation of the content subject matter. Further results elucidate the potential of WIRIS quizzes to improve the overall performance of students in electrical engineering as to their performance on paper and pencil assessments on the same subject content.

Mora, Mérida, and Eixarch (2011) argue that WIRIS should be reckoned as a useful mathematical tool to communicate mathematics in online and distance education. These researchers elaborated on the use of WIRIS in the computer science department at the University of Malaga. They posit that through WIRIS, randomized questions could be posed which further enhanced self-assessment and improved online learning material that supported mathematics education. Moreover, Xambó, Eixarch, and Marquès (2002) assert that the use of WIRIS can promote the conceptual understanding of mathematics since learners can examine in much more detail mathematical concepts in a shorter amount of time than paper and pencil exercises would allow them to do.

Evaluation research was conducted by Marquès, Eixarch, Casanellas, Martínez and Smith (2006) on the usability of WIRIS. These researchers designed a prototype called the Le Active Math project, where they evaluated users on the use of WIRIS for a calculus course at Edinburgh University in the United Kingdom. Not only did they experience positive feedback from participants using WIRIS, but they also provided evidence that utilizing the WIRIS editor increased the participants' mathematics performance.

As seen from the above literature studies the use of WIRIS proves to be promising. Although these studies were done at the university level, investigating the use of WIRIS at school level is

not yet investigated. This research study is thus an attempt to discover whether WIRIS do provide possibilities to facilitate mathematics learning for Deaf and H/H learners.

The next section discusses the feedback feature of WIRIS and Moodle quizzes.

4.8.6 Feedback within quizzes

Rich (1999) asserts that feedback is an activity of conveying or receiving information based on your performance on a certain task. In other words, it's a means to inform individuals of how effective they were. Moodle includes two types of feedback i.e. Overall Feedback (OF) and General Feedback (GF) (Rice, 2011). On the one hand, OF refers to feedback given for the score on the entire quiz. In other words, the boundaries of the grades are set and based on learners' individual scores; the feedback is given for that grade boundary. On the other hand, GF refers to feedback given per question, which is the same for all students irrespective of what they score on that question. As a result, you can create a different feedback for each question type.

Butler, Pyzdrowski, Goodykoontz and Walker (2008) found that noticeable improvements could be seen in quiz scores and performance of students who received immediate feedback in online quizzes. These researchers conducted a study with 373 university students on the use of comments in a Pre-Calculus course making use of WebCT. Not only did they find that students who received feedback had a higher quiz average than those that didn't receive any comments, but they also discovered that the No feedback group made the same mistakes when they retake the test. As for the Feedback group, they learned from their errors and received better marks the second time they took the test. Essentially, this is an indication that students who received feedback, made use of the opportunity to adjust their thinking processes regarding their original answers and modified it making use of the feedback while the No Feedback group didn't have this opportunity.

On the other hand, Brothen, Daniel, Finley, and Force (2004) argue that immediate and meaningful feedback is an essential feature of online quizzes. Supporting the view of Brothen et al. (2004) I am of the view that for feedback to be meaningful, it should be designed to shape individual learning. In other words, feedback should not only include the right or wrong answers but a complete breakdown of how the problem was approached, what the relevant information

was and the formulation of the solution. My point here is, by providing learners only with the correct answer, stimulate opportunities for memorizing answers and not for approaching and solving the problem. Essentially, this also means that no learning takes place, and when values within questions are changed, the learners are lost because they didn't master the skill to solve the problem.

4.8.7 Reporting quiz results

Reporting on quiz results consists of the following mechanisms i.e. Grades, Responses, Statistics as well as Manual Grading. Each of these will now be discussed.

4.8.7.1 Grades

The Grades feature within the quiz module allows administrators to view the grades of each student. It provides administrators with a detailed view on grades per question and the overall grade the learners accumulated (Coy, 2013).

4.8.7.2 Responses

The response option within the quiz module allows administrators to see exactly where pupils made their mistakes and what questions they got right. In other words, it provides a detailed view of the response of the students. Also, Moodle makes it easy to distinguish between the responses of students by color coding the responses (Coy, 2013). For example Green for the correct response, Red for incorrect response and Yellow for a partially correct response.

4.8.7.3 Statistics

The statistics feature, also known as the analytics of the quiz module, provides administrators of an analysis of each question the learner answered. In other words, it provides teachers with analytics on the average grade as well as the distribution of scores obtained by students. It also

provides teachers or administrators with an analysis of the quiz structure which includes a representation of best questions and poorly answered questions (which can be removed) (Coy, 2013).

4.8.7.4 Manual Grading

Manual grading provides a detailed description of each item that is in need or has been manually graded. This feature is conducive to specific question types in Moodle specifically the essay question type.

I have found reporting quiz results very useful (Damon, 2015). Because of the detailed view of each learners' response, I know exactly all the incorrect responses of students and where precisely the learners are in need of assistance. Furthermore, intervention measures could be put in place based on the reporting feature within the quiz module. However, a drawback is the manual grading function, especially with the use of essay question types. Quiz results aren't available until manual grading of the essay question is done.

4.9 Summary

The current chapter described online mathematics assessment as an alternative assessment specifically for Deaf and H/H learners. From the above sections, it can be deduced that online mathematics assessment has the potential to assist Deaf and H/H learners in their struggle with paper and pencil mathematics assessments. Also, the use of Moodle and WIRIS based quizzes as a possible mode of presenting mathematics assessments were also discussed, and it's potential to eliminate obstacles PPA present. Although there are different views on the validity and reliability of online assessments those that do use it agree that features such as immediate feedback, various modes of reporting, multi-representation within quizzes as well as linking it to other modules within an LMS.

The next chapter focusses on the methodology of the current research study.

CHAPTER 5: METHODOLOGY

5.1 Introduction

This chapter is structured in the following manner i.e. the research design, the multiple methods of data collection as well as the data analysis techniques. Firstly, this section describes the research design and the rationale for choosing the particular design. Secondly, it includes the sampling methods employed and why it was chosen. Thirdly, it provides empirical evidence in the form of semi-structured interviews, web-based observation, field notes and reviewing of documents, as data collection techniques. Finally, the chapter includes a detailed description of the data analyzes technique, with the aim of assisting the participants and the researcher to answer the research question which is: *How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners?* The chapter concludes with delineating the limitations of the research study.

5.2 Research design

Since this study is in line with an exploratory and action related research, a more flexible research design was needed. Flexible, in this case, means that different facets of the phenomenon under study should be taken into consideration.

5.3 Research philosophy

Every research project, whether big or small, should be underpinned by a philosophical foundation which guides the design and implementation (Denscombe, 2010). Mostly, a philosophical foundation relates to the view the researcher holds in connection with the research topic, the research question, the methodology and the type of inquiry, what constitutes useful information as well as the nature of the inferences being drawn from the particular inquiry. For a researcher to mentally perceive the social world, he has to comprehend and adopt a perspective on the following three concepts such as “ontology, epistemology, and paradigm” (Denscombe,

2010). These three concepts will now be discussed and how it relates to the current research project.

5.3.1 Ontology

The current research study adopts a constructionist view and specifically in line with Von Glasersfeld (1989) principles of constructivism which includes: “(1) knowledge is not passively received but actively built up by the cognizing subject; (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality” (p. 114). This view is also congruent to what Ritchie and Lewis (2003) refers to as idealism, which maintains that one can only comprehend reality through socially constructing it within the human mind as oppose to realism and materialism. Therefore, this study is the view that learners can construct their own mathematical knowledge if presented with meaningful experiences. Essentially, this entails providing students with opportunities and the right tools to make sense of the knowledge they accumulate.

The next section focusses on epistemology and how it relates to the current research study.

5.3.2 Epistemology

This study is in line with the view that humans become knowledgeable only when they interpret the world around them and give meaning to it and thus without humans, no reality exists. This view the study adopts falls under the umbrella of interpretivism (Denscombe, 2010, Hammersley, 2013). Essentially, this study is of the view that information isn’t attained by Deaf and H/H learners but constructed and reconstructed by them and that these learners come to know reality by interpreting the world around them. In other words, interpretivism believes that individuals become acquainted with themselves and their social worlds and that the manner in which they give meaning to reality is influenced by the culture they are established in and that this cultural lens shapes their judgment and actions. This view is also in line with a constructionist ontology of reality.

Accordingly, the teacher-researcher cannot comprehend the rationale behind the actions of individuals with or without certain attributes. Therefore, only through understanding how Deaf and H/H learners make sense of the OMA and their actions according to their interpretation of the OMA, the teacher-researcher can come to know the realities that exist. This, however, cannot be accomplished without the researcher's personal accumulation of knowledge and not "seek to achieve procedural objectivity" (Hammersley, 2013:27).

The next section describes qualitative research.

5.4 Qualitative research

The view of qualitative research that this research study adopts is proposed by Hammersley (2013). It defines qualitative research as a "form of social inquiry that tends to adopt a flexible and data-driven research design, to use relatively unstructured data, to emphasize the essential role of subjectivity in the research process, to study a small number of naturally occurring cases in detail, and to use verbal rather than statistical forms of analysis" (Hammersley, 2013:12).

Accordingly, the current study will illuminate the learning practices of Deaf and H/H learners which becomes visible through field notes, interviews, test scores and journal entries (Denzin & Lincoln, 2000).

5.5 The Rationale for choosing QR

The question one can ask is: Why choose QR? The most obvious answer would be, the research question dictates using QR. With reference to the current research question: *How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners*, it prescribes a particular methodology to conduct the research i.e. QR. Also, QR allows the researcher to investigate a phenomenon through the experience of the participants (Walliman, 2010; Corbin & Strauss, 2014). Indicating that the research process becomes a discovery of participants' thoughts and ways they give meaning instead of a rigid preplanned endeavor.

Since the principal aim of QR is “insight, enlightenment, and illumination”, the researcher can use QR to get a detailed account of the current situation via the participant’s experience in their natural context (Burton & Steane, 2004:160). Unique to the present research study, our (researcher and participants) quest were to examine the Deaf and H/H learners’ experience with online mathematics assessment. In other words, we are interested in the Deaf and H/H students’ subjective thoughts in how they interact with the online mathematics assessment. How it changed their thought processes or the transformation of the assessments through their interactions and suggestions. For this reason, QR is the most appropriate choice for the current research study.

Also, since I am a researcher and want to contribute to understanding a specific phenomenon in my particular field of interest by providing new interpretations, I am of the view that QR is a viable research paradigm to achieve this goal. Not only does it require my direct interaction with the situation and participants but I will also be faced with real complexities of the world and other challenges the participants and I must face and try to understand and overcome.

The next section describes the research strategy and the particular research strategy employed in the current research project.

5.6 Research Strategy

The current study, which involves the schematic plan of action the teacher-researcher intends to use, is classified as an empirical study, specifically, Participatory Action Research (PAR) which is contained or a subset of Action Research (DePoy & Gitlin, 2011; MacDonald, 2012; Mouton, 2012).

The next section will discuss PAR and the rationale for using the particular research strategy in detail.

5.6.1 Participatory Action Research

PAR is defined by Whyte (1991) as a method to increase the confidence, rights, and status of people by utilizing their own know-how within the research process and therefore making the

research study more applicable. In other words, members of a community in coaction with the researcher come to know and understand their own problems better and contribute to viable solutions to these problems. Moreover, it means that as participants of the research study, they engage in identifying a problem, accumulating and examining data and applying possible solutions to the problem in order to improve their social conditions. From my own perspective, I believe that participants have valuable information about their own social contexts and this information is vital for any researcher. So, to include them in the decision-making process from start to finish is a confirmation that the researcher acknowledges the value they might add to the research study and that they are not just seen as mere subjects in the research process.

In line with the above perspective, PAR's aim is to emancipate individuals and to empower them to bring about social change. Therefore, PAR is not just about adding to the knowledge base, but a search for solutions to real-world problems and actions towards these problems and in the process empowering participants which further might lead to social change and the uplifting of communities (DePoy & Gitlin, 2011).

Furthermore, PAR is underpinned by the premise of collectively finding solutions to local problems, acting on these solutions which result in empowering participants to enrich their lives. The philosophy which underpins PAR is in line with the "postmodern tradition that embraces a dialectic of shifting understandings" whereby "objectivity is impossible" and "multiple or shared realities exist" (Kelly, 2005:66). Essentially this means that multiple perspectives of a phenomenon exist, and when individuals are included in the research process, these views can collectively contribute to solutions and actions to the specific problems. Moreover, it also means that PAR is in contrast with scientific research methods which focus on the cause and effect approach and provide an alternative approach to local participation and action. Along the same lines, McIntyre (2002) asserts that PAR can result in the foundation of a working platform where participants and researchers can co-construct their understanding around phenomena that negatively impact their existence.

Ritchie, Lewis, Nicholls and Ormston (2013:67) argue that PAR "is a collaboration between researcher and the population that is the focus of research, with a core aim being to enact positive change for those involved in the research process." Basically, the authors are saying that a

working relationship between the researcher and the participants should be established. Furthermore, the participants should have a prominent role in reshaping their current practices.

Mouton (2012) on the other hand argue that PAR emphasizes the inclusion of all the research participants in the design, with the aim of changing the social condition of the participants. In other words, the participants play a crucial role in their own emancipation. This view further emphasizes the fact that every phenomenon has multiple perspectives. Accordingly, these aspects can be transformed into a collective practice through social interaction, one in which all participants can benefit.

These researchers all agree that through the use of PAR, the participants will not only gain insight into their own practices but through collaboration, they may produce new knowledge conducive to their own empowerment and becoming change agents of their own social conditions. Therefore, both researcher and participants are provided with opportunities to contribute to the knowledge base which in turn creates space where both parties (researcher and participants) can acquire new knowledge and skills.

5.6.2 The roots of PAR

PAR originated as a result of studies done by Lewin (1944 in MacDonald, 2012) who is in effect also the father of action research. He (Lewin) was a German physiologist who was of the view that individuals would be more incited about their conditions if they were part of decision-making processes, particularly when their jobs are concerned. The key point in this argument is that individuals are more motivated when their voices are being heard and when they feel that they can contribute towards improving their circumstances. Although this point is highly debatable, it appeared to be one of the key elements within the PAR process.

According to McIntyre (2002), PAR has its roots in Paulo Freire's view about change, whether personal or social, is dependent on careful evaluation and judgment. His PAR view suggests delegating power to the poor and marginalized especially issues relating to literacy, correcting abuses based on land ownership as well community structures (Freire, 1970). He elicited the marginalized and poor to become aware of their own social and economic conditions and to critical reflect on their own well-being with the purpose of changing their current positions.

McTaggart (1991) on the other hand, posits that a variety of definitions exist for PAR depending on the context it is being used. From my own experience doing web searches and making use of different search engines, I have come across a vast amount of PAR definitions which differs from context to context. However, these definitions all include concepts such as emancipation, improving social conditions, empowerment, participation, shared decision-making, etc.

The next section describes the principles of the PAR process.

5.6.3 Principles of PAR

Balcazar, Keys, Kaplan and Suarez-Balcazar (1998) identified general principles of PAR specific to people with disabilities. We have adjusted these laws to accommodate Deaf and H/H learners within the current research study. These principles include:

- a) *Deaf and H/H students participate in identifying, defining, analyzing and solving the problem.*

This principle highlights the responsibilities of D/HH students within the current research project. It emphasizes that they will adopt certain roles and will not be mere subjects participating in the research study. This is crucial since it will guarantee that the research objective i.e. to improve the quality of life off D/HH learners, will stay in check. As a result, D/HH students' participation isn't circumscribed by only different problem areas but getting involved in action towards solving the problem areas.

- b) *Deaf and H/H learners participate in the research process, which strengthens the authenticity and the quality of their social conditions.*

Since Deaf and H/H students collectively participate in the research study, they contribute objectively and subjectively. This means that they provide insight of their experience within their current situations and together with the researcher's perspective on the situation, it paints a clearer picture of the problem situation. Therefore, the knowledge accrued from the multiple perspectives can be utilized to bring about change

within the community of Deaf and H/H learners. Moreover, it might also highlight problems faced by these students isn't due to their disability but other social factors within the community (Balcazar et al., 1998). In my own view, when Deaf and H/H learners are emancipated from "social branding" accompanying being Deaf, they might claim their place in their respective communities.

- c) Through participation in the research process, Deaf and H/H learners become conscious of how effective they can be.***

When Deaf and H/H learners participate in the research process, they might become aware of the value they can add to the research. Essentially, this means when Deaf and H/H learners become aware of the contributions they can make towards changing their social condition it might enhance their confidence which in turn can empower them even more (Balcazar et al., 1998). Moreover, I am of the view that by empowering Deaf and H/H learners might also result in them becoming more autonomous in decision-making processes.

- d) The sole aim of the research study should be to empower Deaf and H/H learners, which might lead to an enhancement in their way of living.***

A process of critical reflection is needed in order to change your quality of life. For this reason, space should be provided for Deaf and H/H learners to reflect critically on their current conditions. I am of the view that by continually reflecting and adjusting your current situation it can empower you to approach your situation differently and seeking solutions to your own needs in a joint fashion. In other words, Deaf and H/H learners participate in shaping the research in order to fulfill their specific needs.

The next section includes the characteristics of PAR.

5.6.4 Characteristics of PAR

The characteristics of PAR includes the following:

- “PAR as cyclical
- PAR as participatory
- PAR as systematic
- PAR as dynamic
- PAR as developmental
- PAR as critical” (Crane & O’Regan, 2010:13)

These characteristics will now be discussed below.

5.6.4.1 PAR is cyclical

PAR is reported by different literature studies as being cyclical in nature (Crane & O’Regan, 2010). This cyclical model is based on Lewin’s (1944) work of structuring the action research process through cycles, such as observing, reflecting, acting, evaluating and modifying (MacDonald, 2012). A cyclical model refers to research that utilizes a PAR approach consisting of recurring cycles. Since the objective of PAR is to improve social conditions, each of the cycles isn’t viewed as the final cycle but further analyzed and examined by both parties (researcher and participants) with the aim of making improvements to the previous cycle (DePoy & Gitlin, 2011). Figure 5.1 below illustrates the different cycles within a PAR cycle.

The PAR Cycle

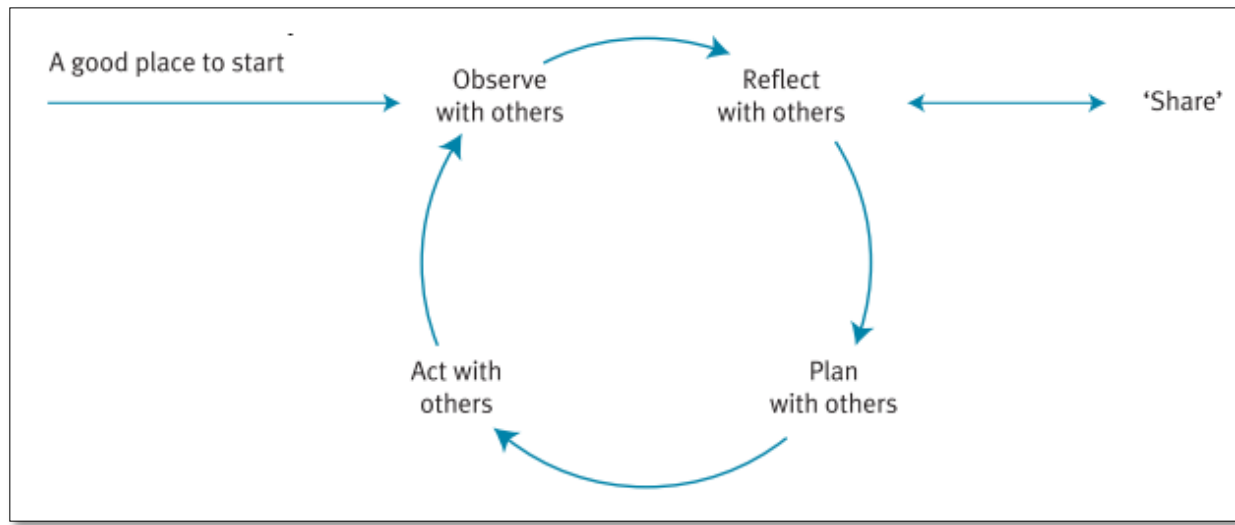


Figure 5.1: The PAR Cycle. (Adopted from Crane & O'Regan, 2010:11)

As seen from the illustration of the cyclical model of PAR, participants, and researcher collectively engage in the research process from start to finish. Therefore, the researcher isn't seen as the sole provider of knowledge the Deaf and H/H learners share in all decision making processes.

This PAR cycle was extended for the purpose of the current research study as can be seen in figure 5.2.

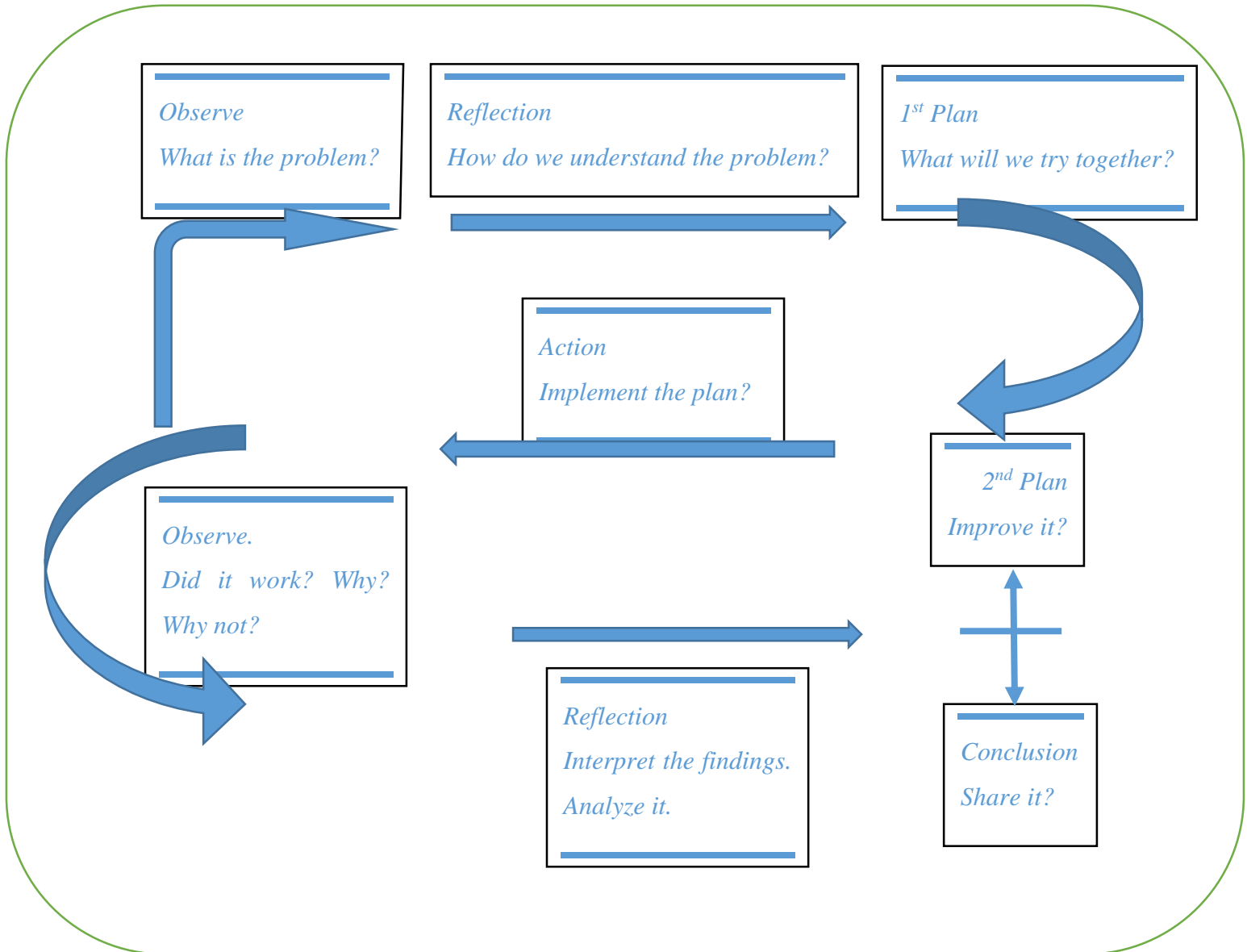


Figure 5.2: Extended PAR Cycle. (Adapted from Crane & O'Regan, 2010:14)

The description below will provide a clearer picture of what figure 5.2 entails. Keep in mind that the whole process is done in conjunction with the participants.

Observe

First and foremost, observation is done on the current state of the phenomenon. During the observation stage, the participants can be asked to evaluate what they are encountering in their classrooms with particular reference to mathematics assessments. The participants are asked to describe in detail what is happening, and the researcher can also get involved by recording the current state of mathematics assessment practices of Deaf and H/H learners.

Reflection

This step also includes detaching oneself from the situation and intensely looking at what is actually happening in the current situation. This step can also include communicating with role-players about how they experience the current phenomenon as well as collaborating with participants to get a clearer picture of what is happening. Also, ideas between participants and researcher can be shared by means of comparisons.

1st Plan

Together, a plan of action is constructed. The plan of action is based on the shared interpretation and ideas that eventually led to asking a question. After careful reflection, the researcher in collaboration with the participants devises a plan by designing a strategy to answer the question. In other words, they devise a plan of action.

Action

The stage includes following the plan the researcher and the participants devised carefully and consistently. Within this step, communication is of utmost importance. Therefore, the researcher and the participants should continually communicate what is happening, and these findings should be captured.

Observe

After taking action, observation should continue in order to understand what is happening. Observation is thus a crucial step in the whole PAR cycle since it will provide the researcher and participants with useful evidence which can be added to the conclusion being drawn. This step can be repeated as many times as possible.

Reflection (Interpret findings and analyze it)

Continual reflection will provide the researcher and participants with an in-depth understanding of what is working, why is it working or why it isn't working. It will also provide useful information on the progress of the PAR cycle and whether further repeats in the cycle are needed.

Conclusion

If the reflection phase indicates that valid conclusions can be drawn from the PAR cycle, these findings can be shared with other stakeholders with the aim of implementing it at other institutions. However, if the reflection cycle indicates otherwise, a second plan needs to be devised to provide an alternative.

2nd Plan

The second plan can either be an alternative if for some reason the first plan failed or it can be an improvement to the first plan. So, depending on the outcome of the first cycle, the second plan will or will not be implemented.

Additionally, one should be cognizant that the PAR cycle is not a one-dimensional process. In other words, the flow between the elements within the sequence can be altered. As a result, different elements can take precedence over others or some parts can be completed together.

5.6.4.2 PAR as participatory

The focal point in PAR is those that are affected by their circumstances should be the ones participating in the research (Crane & O'Regan, 2010). In other words, the participants should not be treated as subjects alone, but they should play an active role in the research process from start to finish. Furthermore, their insights and interpretation of their current situation should provide useful information on the phenomenon as well as answers to possible questions (Whyte, 1989). A point that needs to be taken into consideration though is that not all participants will add the same value to the PAR process. The focused observation skills of the researchers will enable him/her to distinguish between more valuable participants to least valuable participants. Whyte (1989) argues that it is these participants that will become vital collaborators to the research project.

5.6.4.3 PAR as systematic

The Goal of PAR is to improve current practices with the assistance of all those affected by the current social conditions. In order to accomplish this goal, it should be characterized by order and thorough planning (Crane & O'Regan, 2010). Since PAR is cyclical in nature, vast amounts of information need to be interpreted and analyzed by the researcher and the participants. To speed up the process and to provide each participant with a clear understanding, it has to follow a sound system i.e. structure. In other words, not only should it be logical but it should provide enough space for continual reflection to see whether progress has been made or whether new plans should be put in place. Therefore, it is of utmost importance to document and capture all information, discuss this information to find its meaning in order to provide useful conclusions.

5.6.4.4 PAR as dynamic

PAR needs to be flexible in nature which means it must be able to adapt quickly to a new design. This means that PAR should be quickly transformed as discussions and reflection processes proceed. Moreover, it also means that the whole PAR process can change as new information becomes available and therefore should not have a fixed format that cannot be altered (Grant,

2007). For instance, following a rigid plan presupposes that the desired outcome is expected, which is not the aim of the PAR process. Also, a rigid plan will ignore any obstacles that surface, while a more dynamic design will see these barriers as new insights which in turn might provide useful information and assist in finding the meaning of the problem.

5.6.4.5 PAR as developmental

PAR is not a linear process which starts at point A and ends at point B. This means that it improves as the cycles are implemented and as participation increases. The objective is not to find answers to the main questions first. These question can be divided into smaller questions which can be answered first before heading to the bigger issues. Trying to find answers to the more trivial question provides opportunities to go through the PAR cycles, which will, in turn, strengthen participation and prepare all participants for the bigger questions (Crane & O'Regan, 2010).

5.6.4.6 PAR as critical

PAR is crucial in the sense that it is underpinned by critical reflection. Essentially this means that the voices of those affected by the social conditions should be heard through the process of introspection and providing opportunities for all participants to raise their voices. To accomplish this, principles such as “relationship, inclusion, and justice” are embedded within the PAR process.

The next section includes the strengths of PAR.

5.7 Strengths of PAR

If correctly implemented, PAR has the potential to recognize and develop the strengths and skillfulness of those involved in the PAR process (Crane & O'Regan, 2010). Essentially, this means that PAR might enhance the expertise of participants and their communities. These

researchers discovered this particular strength of PAR while implementing their Reconnect Program, an early intervention program, in Australia for homeless youth.

A further strength of PAR includes recognizing the value of human interaction and interconnection between individuals. This point highlights the importance of people working together and getting involved in community affairs with the sole objective of improving each other's' lives. Stronger relationships might also foster trust between individuals and a better appreciation of the individual 's capacity to add value to the research project.

Moreover, stronger relationships between individuals might produce a better understanding of the problem situation and in return, more in-depth information to work with in finding solutions. A clearer picture of the problem situation is obtained by reflecting on each participants' interpretation and experience of the social condition (Whyte, 1989). As a result, the social situation is viewed from an array of perspectives which provides a rigorous account of the current events and as the PAR process unfolds.

The next section focuses on the challenges of PAR.

5.8 Challenges of PAR

An in-depth literature review has highlighted an array of difficulties while doing PAR (Nyden, Figert, Shibley & Burrows, 1997; Balcazar et al., 1998). Many of these challenges are not directly linked to the current research study. For this reason, I will only discuss challenges that are relevant to the current research study.

5.8.1 Developing equal partnership

The biggest challenge facing researcher is establishing a connection with all the participants. This has become problematic since participants were treated as subjects only participating in the investigator's pre-developed plan.

5.8.2 Waiving your control and manipulation as the research specialist

Sharing a partnership throughout the whole research process forces the researcher to abandon his dominant practice of sole investigator and acquiring the expertise of all participants. This also means acknowledging the useful information participants possess and the value they can add to the research project. On the other hand, through participation during the whole research process might foster a sense of ownership in decision-making (Whyte, 1989). Furthermore, it might also provide a clearer picture of the actual state of the current situation.

5.8.3 Continuance of the PAR process

The PAR process is not a single step in a sequence but a continual refinement of the original plan. In other words, completing the first cycle does not mean that you have completed the process as a whole. Since the elements of the sequence do not follow a linear pattern and that any element can follow another, continual refinement as information becomes available should not be disregarded. Since the aim is finding information that is rich in significance and implementation, in-depth discussions and interpretations are needed which might be difficult to complete in a single PAR cycle.

5.8.4 Unplanned effects of PAR

Since PAR involves communication, focused observation, joint participation and critical reflection, different interpretations need to be understood and acknowledged. As a result, unplanned effects should be expected and dealt with as it surfaces. For this reason, following a rigid plan or applying a linear framework to the PAR process might impinge the validity of the outcome of the PAR process. Therefore, enough space should be provided for unplanned effects of PAR.

5.9 PAR as an empowerment endeavor

The objective of all PAR projects is to encourage action towards joint knowledge creation by the researcher as well as participants with the aim of empowering those directly affected by the phenomenon (Whyte, 1989; Kemmis, 2008; Rahman, 2008; MacDonald, 2012). Essentially, this means that empowerment is a key ingredient which separates PAR from any other Action Research methodologies.

Rahman (2008) and Kemmis (2008) agree that empowerment can be attained through raising consciousness, liberating participants, learning and fortifying participant's problem solving capabilities. These respective ways of achieving empowerment will now be described with particular reference to learning and how learning will be used in the current research project to promote empowerment of Deaf and H/H learners.

5.9.1 Raising consciousness

Raising consciousness refers to eliciting the awareness of participants or developing self-awareness of participants. This "conscientization" can be achieved through the use of the participants' own knowledge (Rahman, 2008:50). In other words, Rahman (2008) argues that self-awareness can be obtained by admitting participants to join in the research endeavor and acknowledging that their own personal experience and interpretations can add value to the research.

5.9.2 Liberating participants

A project is characterized as a PAR project when characteristics of emancipation or liberation are involved. Liberating participants pertain the freeing of the minds of participants and allowing them to critically reflect as well as querying their own thinking processes (Kemmis, 2008).

5.9.3 Learning

One of the aims of PAR is learning (Chesler, 1991). Along the same line, Fals-Borda (1991) posits that adult education is one of the three fundamental components of PAR. To adopt this view, one should consider education and specifically ‘learning’ as an inseparable part of PAR. In other words, learning should not be seen as just a characteristic of a PAR project but should be regarded as a recurring process (Greenwood, Whyte & Harkavy, 1993). This might also be the reason why proponents of PAR denote PAR as an “approach to education” (Sarri, R.C. & Sarri, 1993:100).

Education or learning is seen by all proponents of PAR as an essential component in empowering participants (Chesler, 1991, Lewis, 2004). Essentially, this means that empowerment can be achieved by increasing opportunities for participants to learn. These opportunities might include obtaining a newly developed skill set or learning how to acquire or discover new knowledge (Chesler, 1991).

Also, as highlighted by the above views, empowerment considers information and individual abilities as key features (Fals-Borda, 1987). Accordingly, participants should be trained in developing better perspectives as well as more detailed realization in order to provide a rich description of their social contexts. This can be accomplished through collaboration with peers and others and by continually reflecting on what is happening. As a result, knowledge is constructed, which provides participants with a better understanding of their circumstance and new found knowledge can assist them in making better-informed decisions and therefore empowering them.

PAR is devoted to the perception that individuals can be educated to reflect critically on their own social conditions. Accordingly, PAR should be embedded with opportunities for participants to be educated in self-reflection (Maclure & Bassey, 1991). In other words, participants should learn how to analyze their current situations critically, discover new approaches to sources of difficulties and new ways to apply accumulated knowledge. However, participants should be able to give voice to their own information processing as well as that information obtained from outside sources. Moreover, they should also be able to reduce this accumulated information in line with a particular coherent entity.

Another feature that PAR should promote within the learning process is to provide opportunities for participants to become self-aware of their own knowledge and abilities (Rahman, 2008). In essence, this means that each participant should be aware of their increased confidence, rights and status and based on this, they can contribute collectively with regards to problems experienced in their social environments. In other words, they themselves should be conscious of the fact that they can become change agents within their particular communities.

5.9.4 Fortifying participants' problem solving capabilities

As empowered individuals, they can now investigate and approach their own problems differently and achieve their own goals more frequently. As stated by McTaggart (1991), participants should, above and beyond all other considerations be allowed to make their own inquiries. Accordingly, it is of paramount importance that participants be educated in research techniques and how to interpret accumulated data (Fals-Borda, 1987).

The next section sheds light on the rationale for using PAR as a methodology in the current research study.

5.10 The rationale for choosing PAR

Balcazar, Keys, Kaplan and Suarez-Balcazar (1998) conducted a study with individuals with disabilities. Not only did they find that PAR provided opportunities for the “voices” of individuals with disabilities to be heard, but they also found challenges doing this type of research with persons with disabilities. The results of the study indicate that PAR has the potential to increase participation and create space for valuable contributions on the part of individuals with disabilities.

When we look at the previous and current curricula, the apparent discovery is that it was written with hearing learners in mind. This pertains not just to the structure of the curriculum but also to the teaching and assessment practices. So, one can adopt the stance that the Deaf and H/H learners are forced to learn “something” without considering their disability. Essentially, they are “kept out” or “left in the dark”, and the very curriculum that should provide them with access to

further education and training of career advancements is the obstacle that hinders them from acquiring new knowledge and skills. This occurs since there is no Deaf and H/H representation while constructing state curriculums. In other words, no representation means no input or no understanding of the needs of learners identified as Deaf and H/H. A one size fits all curriculum is adopted, and Deaf and H/H students are expected to perform equally well as their hearing counterparts.

In order to emphasize the importance of inclusion of Deaf and H/H individuals in decision-making processes particularly when the curriculum is concerned this research study adopted a PAR approach. Deaf and H/H learners' voices need to be heard when it comes to constructing learning objects of assessment materials which they are going to use. This research thus sets the stage to incorporate Deaf and H/H learners in the research process from start to finish in order for them to take an active part in changing how they learn and how they are being assessed by addressing their own personal needs specific to assessment practices.

By choosing PAR as a research approach Deaf and H/H learners are provided with an opportunity to become researchers. In other words, they learn how to accumulate knowledge, critically analyze it as well as interpret it by acknowledging others' opinions. Moreover, they work on problems specific to their own needs and thus collectively try to find solutions to their own problems (Reason & Bradbury, 2008; Rahman, 1988).

Including those that are directly affected by the phenomenon can increase the authenticity of the results obtained from the research. Therefore, by allowing Deaf and H/H learners to participate in this research study not only enhance their motivation to search for answers to a problem but they are also more committed to finding a solution to a particular issue. Furthermore, to gain a better insight into the problem and to understand why the problem presents an obstacle to the Deaf and H/H learners, the researcher can gain insight into their understanding and experience of the problem.

The following section describes the site selection, sampling, data collection methods and data analysis techniques utilized in the current research study.

5.11 Site selection and sampling of target population

A school for the Deaf and H/H learners in the Western Cape, specifically Cape Winelands, were chosen as the site to conduct the research. School ‘*dee*’ (a pseudonym used) is a school situated in the Western Cape and currently providing education for 230 Deaf and H/H learners. These students attend school ‘*dee*’ from age 3 up until 18 years. The school accommodates Grade R till Grade 9 and then students can choose to either advance their studies by enrolling in Grade 10, at another school for the Deaf or continue their education by selecting occupational training courses at school ‘*dee*’.

The rationale for choosing school ‘*dee*’ as the research site is twofold. Firstly, since I am a mathematics teacher at school ‘*dee*’ and already know the particular learners. Accordingly, I already have a working relationship with them; it might be easier for them to confide in me about problems they experience in school, specifically mathematics related. Secondly, Deaf and H/H learners are struggling to understand and complete written assessments without the use of some kind of accommodation or an alternate assessment. Accordingly, they fail the exam component of SBA and therefore fail subjects like mathematics. This has become a huge problem, particularly when Deaf and H/H learners can’t get access to FET colleges. For this reason, the site was chosen to investigate the issue further.

The target population consists of eight Senior Phase learners, who are Deaf and Hard of Hearing and attending school ‘*dee*’. These Deaf and H/H students are between the ages of 13 – 15 years and were selected to take part in this research project on the basis of their hearing loss. Fraenkel and Wallen (1993) posits that this type of sampling is called a homogenous sampling which refers to the same characteristics or traits the sample group possesses.

Secondly, this research project sets out to address problems Deaf and H/H learners experience with paper and pencil mathematics assessments and to investigate the use of online mathematics assessment as an alternative. For this reason, it was deemed necessary to include Deaf and H/H learners as the sample population as it directly influences them. Thirdly, since this research project makes use of PAR as the underlying research technique, including Deaf and H/H learners in the research study will provide the researcher with a better understanding of the current

obstacles Deaf and H/H students experience with PPA and therefore will also make the context more authentic.

The illustration (Table 5.1) below depicts the sample population.

NO	Participants	Gender	Disability	Cause of disability	Hearing aids	Means of communication
1.	User 1	Female	Deaf	Born deaf	2	Sign Language
2.	User 2	Female	Deaf	Born deaf	2	Sign Language
3.	User 3	Female	Deaf	Born deaf	2	Sign Language
4.	User 4	Female	Deaf	Born deaf	2	Sign Language
5.	User 5	Female	Deaf	Born deaf	2	Sign Language
6.	User 6	Male	Deaf	Born deaf	0	Sign Language
7.	User 7	Male	H/H	Meningitis at young age	2	Speech + Sign Language
8.	User 8	Female	Deaf	(emotional defect)	0	Sign Language
N = 8 D EAF/ H/H		Female = 6 Male = 2	DEAF = 7 H/H = 1	Born Deaf = 6 Other causes = 2	Hearing aids = 12	Sign Language = 7 Speech + Sign Language = 1

Table 5.1: Personal information of Grade 8 Deaf and H/H learners, relating to their hearing loss

The table above provides a detailed illustration of the physical disabilities the participants are faced with. What follows is an overview of what is included in the table.

The participants consisted of eight Deaf and H/H Grade 8 learners. Also, six of these students were female, and two were male. Whilst seven of them were completely Deaf as from birth, and one was H/H following illnesses experienced during their younger years. Although they are Deaf and or H/H, six of them wear hearing aids which assist them with perceiving minimal sound. On the other hand, all of them used Sign Language as a means of communication while only one of

them used speech in conjunction with Sign Language.

5.12 The role of the teacher-researcher

As mentioned in previous sections, the researcher is a mathematics and IT teacher at school 'dee.' He is currently teaching mathematics for Grade 7 to 9 and IT for Grade 4 to occupational training classes. His role as researcher comprises of the following duties:

- Administering the online mathematics assessments
- Conducting and recording of interviews in conjunction with the participants
- Administering web-based observation
- Adapting the online mathematics assessment as suggested by participants
- Administering the cycles of the research technique and providing space for reflection
- Securing the learning environment and providing access to the VLE and OMA
- Updating the qualitative data analysis software with the data extracted from the data collection techniques

To put it succinctly, the researcher becomes the observer and participant, also the co-constructer of new found knowledge with each participant as well as an attentive listener for each learner and adds high value to each participant's ideas and interpretations. It should be noted that the researcher in conjunction with the participants work collaboratively in finding answers to the research question and therefore both their thoughts, arguments and views are accepted and acknowledge.

The next section focusses on the description of data collection methods utilized within the current research study as well as the rationale for choosing these particular methods.

5.13 Data Collection methods

A diverse set of data collection techniques can be employed within a PAR project (MacDonald, 2012). These include focus groups, participant observation, field notes or memos, interviews, questionnaires, documents, and surveys. However, MacDonald (2012) suggest that only 3 of the

data collection techniques should be utilized in order to make valid inferences from the data. Following MacDonald's argument, these three i.e. focus groups, participant observation, and interviews will also be utilized within the current research project as a means of data collection techniques. These will now be discussed with reference to how it was employed in the current research project.

5.13.1 Focus groups

Focus groups are small groups consisting of seven to twelve participants who all share a common problem which is central to the research project (MacDonald, 2012). In other words, all seven to twelve participants face the same challenges and are motivated to act on a possible solution. These participants are also willing to share their experience of the current situation with the researcher and collectively try to find solutions to the problem situation and act on it.

All participants' perspectives should be taken into consideration and treated as worthy of the cause (McTaggart, 1991). For this reason, the researcher should establish a positive learning environment where participants feel at ease to contribute to extracting useful information which in turn can be used to gain a better understanding of the problem situation.

The selected focus groups in conjunction with the researcher decide on the validity of the data, and each contribution is seen as adding to the understanding of the situation. Although this is a collective process, it is still the researcher responsibility to provide the structure of how everything fits in place (McDonald, 2012).

The current research study consists of eight Deaf and H/H Grade 8 learners which form the focus groups. These learners have the same characteristics and share a common problem such as having trouble doing written mathematics assessments. They were thus more than willing to share their ideas surrounding the obstacles written mathematics assessments present and were motivated to find possible solutions to the problem and act on it. Moreover, they were reluctant to share in the responsibility to collectively engage in the research project from start to finish.

5.13.2 Participant observation

Tessmer (1993) argues that observation entails the direct experience of the unfolding of events or viewing how participants experience a phenomenon. Moreover, MacDonald (2012) posits that participant observation is a distinct qualitative data collection technique which provides the researcher with an in-depth view of the experience of participants in a given situation. Not only does this mean that the researcher experiences firsthand the participant's behavior but he/she also interacts with the situation while acting as a participant observer (Kothari, 2004).

During the process of participant observer, the researcher records the whole process as it unfolds by making either field notes, video recordings, audio recordings or capturing log files. This process usually includes the observation of behaviors, actions and other objects within the social environment that the participants interact with (Creswell, 2014). This in effect provides the researcher with a wide angle view of what is happening and a better understanding of what is going on.

The current research project made use of participant observation by way of observing participants as a group and individually as they interacted with the written and online mathematics assessments. The participant observation started while the participants were engaging with written mathematics assessments. The researcher observed their behavior and interpretation of the written content and made use of field-notes to capture what he saw. Furthermore, a researcher's journal was kept to record any change in behavior. The joint observation was also done by the researcher and the participants as they watched each other interacting with the online mathematics assessments. The participants were also presented with a journal within the online environment which they had to document their experiences.

The researcher together with the participants also had access to the log files within the LMS. These log files include information such as time spent on activities, login information, and assessment scores, the frequency of assessments taken, dictionary entries, file uploads, etc. This information also became useful when the data analysis process started (Paulsen & Dailey, 2002).

5.13.3 Interviews

Gillis and Jackson posit that interviews are “face-to-face verbal interactions in which the researcher attempts to elicit information from the respondents, usually through direct questioning” (2002:466). Denzin and Lincoln (2008) refutes this argument and posits that interviews can also take on the form of face-to-face group sessions as well as telephone surveys. Accordingly, interviews are data collection techniques that create space for participants to provide an account of what they are experiencing in their current situation (MacDonald, 2012). In other words, interviews take the form of face to face or telephone questioning, usually structured, semi-structured or unstructured questioning, which provides the researcher with a clear picture of the thinking processes and intentions whilst they present it to the researcher via words (Creswell, 2013).

In contrast to surveys or questionnaires, where the researcher captures the answers to the question and provides the wording for the participants, interviews provide space for participants to describe their experiences in their own words, which is thus an accurate account of the situation. This view is also in line with Paulsen and Dailey’s (2002) view that interviews are a means to obtain descriptive data based on the way an intervention was experienced by the participants. My view is that meaningful information extracted from the interviews can also illuminate successes and drawbacks from the experience with the intervention or program.

Within the current research project, semi-structured interviews were used as a data collection method. Since PAR was used, the interviews were part of the elements within the cycles. First and foremost, the interviews were conducted with the Deaf and H/H learners to extract information regarding their current experiences with written mathematics assessments.

Information gathered from these interviews together with observation was done by the researcher and other students provided a better understanding of the problems these Deaf and H/H Grade 8 learners experience while doing written mathematics assessments.

The second group of interviews was conducted after the completion of the first experience of the online mathematics assessment. Individual students were asked a set of questions ranging from their experience with the online mathematics assessment to what they might change to improve

their experience. The answers they presented was used to modify the online mathematics assessments.

Again, interviews were conducted based on the new experience they had with the modified online mathematics assessments. The interviews continued until all the participants were satisfied that the representation of the online mathematics assessments was what they sought after and would provide an alternative to the written mathematics assessments. All the interviews were video recorded and afterward transcribed and presented to the participants to see whether it was in fact what they had said. Not only did the interviews act as a means of understanding the problem better and improving the current situation but also as a means of reflection on what worked and what features needed attention.

An important point that needs to be kept in mind is that all these interviewees are either Deaf or H/H. As a result, the interview questions had to be translated into Sign Language by an interpreter. The participants had to interpret the questions via Sign Language and provide their answers via Sign Language, which was video recorded and these visual imageries had to be transcribed.

The next section describes the data analysis techniques employed in the current research project and the rationale for using these techniques.

5.14 Data Analysis Framework

This research project falls under the umbrella of qualitative research and therefore utilize qualitative data analyze methods. Qualitative data analysis is the evaluation of focus groups, participant observation, interviews, documents, journal entries and other qualitative data collection methods without converting the data to quantitative specifications (Babbie, 2007; Babbie, 2010; Babbie, 2015). In other words, the information accumulated from the above data collection techniques are examined for its meaning. Accordingly, these words, ideas, and concepts act as valid information that might serve as answers to the research question. Due to the uncovering of massive amounts of data, not all of the data should be considered useful, and the researcher should zoom in on what data can be used to answer the research question (Creswell, 2014).

In order to make sense of all the data, researchers have developed techniques to analyze qualitative data such as coding methods, categorizing ideas which share resemblance and associating ideas and themes together (Ruben & Ruben, 2011). Since different qualitative methods of data collection were used within the current research project, the analysis of the data accumulated from the different techniques was done by means of a qualitative data analysis software such as MAXQDA. All the information collected from the different data collection methods will be uploaded to the software program. The researcher will still go through the data line by line and code it within the program. Not only is this a faster method of analyzing data but comparisons (between codes and how participants' respond to ideas or concepts) can be made by a click of a button.

After administering, recording and transcribing the interviews, the researcher is left with a vast amount of data. As a result, researchers have to use qualitative data analysis techniques. This research study utilizes the framework proposed by Creswell (2014) for analyzing qualitative data. The components of the framework include:

- “organizing and prepare the data for analysis
- Read through the data thoroughly
- Start coding all the data
- Create overarching themes in the data
- Finding possible and plausible explanations for findings
- Ensuring reliability and validity in the data analysis and in the findings
- Interpretation of the findings and results” (Creswell, 2014:248).

The way in which this framework was implemented will be thoroughly discussed in chapter 6. The next section focusses on the limitations and potential problems of the current research project.

5.15 Data validation

The credibility of this research study was demonstrated by means of methodological triangulation. Primarily this involves the accuracy and soundness of the data and in which way the data is congruent to the research question posed (Denscombe, 2010). Both these methods of

triangulation will now be discussed and how it was used in this research project.

5.15.1 Methodological triangulation

This type of triangulation entails the use of different methods in order to compare whether similarity exists between the various data types (Denscombe, 2010). For example, one can use qualitative data and quantitative data and examine whether the findings can be confirmed. Also, within a research project, one can use data obtained from participants, documents, and observation done by the researcher in order to check whether the data can be characterized as valid (Denscombe, 2010). Figure 6.8 illustrates how this type of triangulation was achieved in this research project.

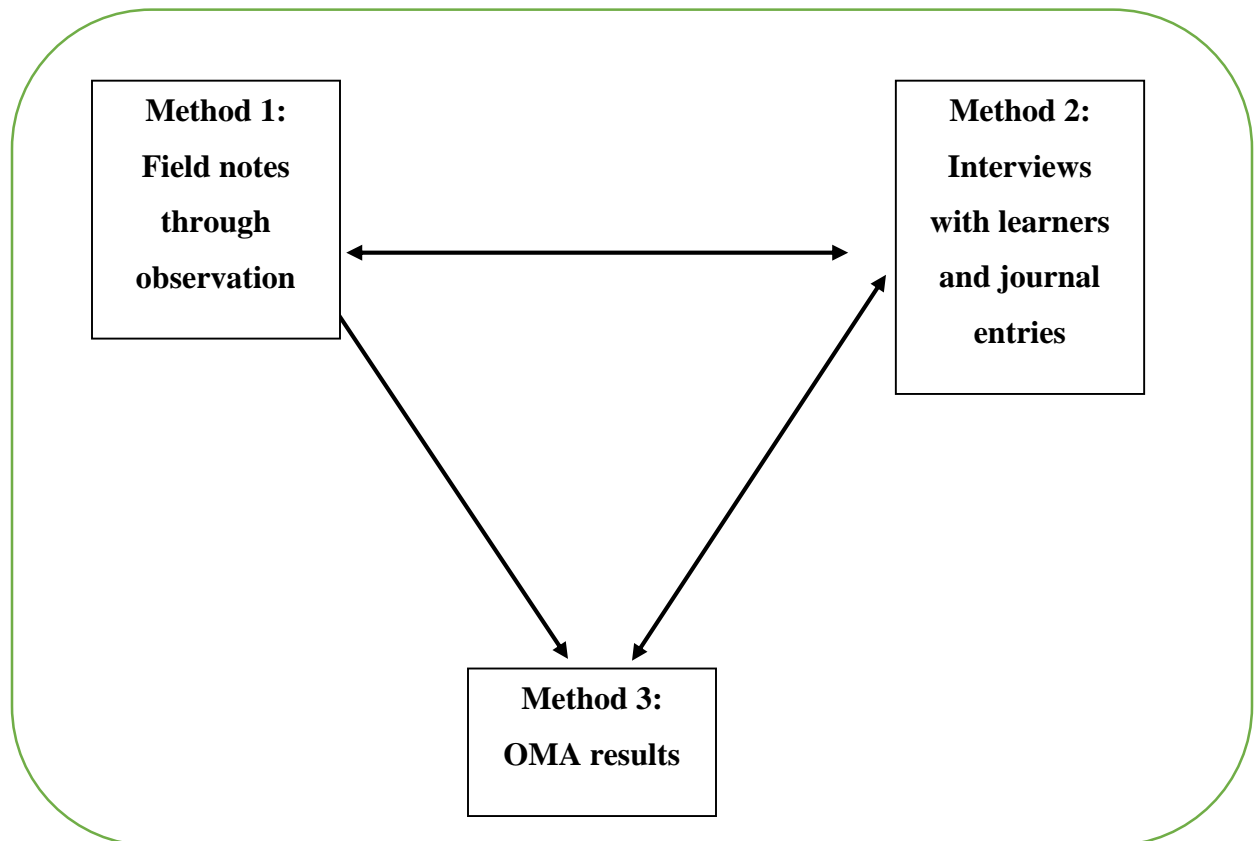


Figure 5.3: The methodological triangulation utilized in the current research project [Adapted: Denscombe, 2010:351]

The rationale for using methodological triangulation was to obtain data from different methods in order to authenticate this research and also to provide an accurate account of the research findings. Moreover, it was also utilized to increase the completeness of the results of the research. Denscombe (2010) argues that using methodological triangulation can provide social researchers of a clearer picture of the integrity of their research findings.

5.16 Delineating the limitations of the current research study

As stated by Marshall and Rossman (2015) a perfect study design is none existing. In other words, all research studies are limited or restricted by some independent factors.

Although no generalizations can be made, the findings of the current research study might be transferrable to other classrooms within '*school dee*'. In other words, results that indicate the advantages of OMA as an alternate assessment for Deaf and H/H learners can be used in other mathematics classrooms where learners are Deaf and H/H. However, it cannot be transferable to mainstream mathematics classes since the nature of the online mathematics assessments for Deaf and H/H learners differ from those of mainstream students. Accordingly, the online mathematics assessments were focalized on the needs of Deaf and H/H students, bearing in mind their disabilities and struggles with written text.

Also, only one content area i.e. Functions was incorporated within the OMA which questions whether the other four content areas can also be integrated within the OMA. In addition, the focus was only on Grade 8 Deaf and H/H learners. Therefore, further research is needed to investigate the use of OMA based on the other four content areas as well as other grades.

Moreover, only eight learners participated in this research study and hence a small sample size which further questions whether the findings can be generalized to another grade eight class.

A point that needs attention here is that this is a qualitative research study, and the focus was on understanding a phenomenon and gaining insight into the problem and finding solutions to the current problem. Therefore, generalization should not be expected since it is not an objective of the present study.

5.17 Summary

To sum up, this chapter shed light on the methodology linked to a qualitative paradigm which includes:

- the research design is flexible, in other words, the research takes place within the naturalistic settings of the phenomenon under study rather than experiments in a laboratory and is modified as the research evolves.
- The data collection methods employed within such a study should also be flexible and presuppose that it is susceptible to the attitudes, feelings, and circumstances of all the participants.
- The dominant data collection techniques employed includes i.e. interviews, observations, document and text analysis, field notes, etc.
- The data analysis includes distinguishing between themes and categories as it evolved and therefore highlighting the complexity of the data analysis process. In other words, no predetermined categories exist. Also, MAXQDA, a qualitative data analysis software is used to analyze the data.
- The aim of the data analysis is to formulate an account of the meaning of the information and not to suggest a cause for the information.
- The reporting consists of providing a detailed description of the participants' experience within their natural settings based on their interpretation, interaction, and knowledge of the phenomenon.

The next chapter will illuminate the findings of this research study and provide possible recommendations for future research.

CHAPTER 6: ANALYSIS AND FINDINGS OF THE CURRENT RESEARCH STUDY

6.1 Introduction

This section provides a detailed discussion of the results of this research study by illuminating the researcher, as well as the participants' interactions with the OMA based on the function concept. Since this is a PAR research project as described in Chapter 5, the analysis and findings will be dealt with through the cycles of the PAR process. The research study progressed through three phases which consisted of all four PAR cycles i.e. observation, reflection, planning, and action.

The research question that drives this research study is: *how can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners?* Secondary questions that relate to the central research question are:

- What characteristics should online mathematics assessment adhere to provide mathematics teachers with insights into the cognitive functions and dysfunctions of Deaf and H/H learners?
- How can the use of online mathematics assessment as an alternate assessment mediate the learning process of Deaf and H/H learners?
- What are the operational implications of online mathematics assessment for Deaf and H/H students as well as for teachers?

6.2 Analysis of the data

The aim of analyzing the data within this research project was to become familiar with the data accumulated from the data collection techniques (Denscombe, 2010). In other words, to become better acquainted with the data and to interpret what it means. To achieve this the data from the interviews, journal entries and field notes were transcribed and broken down into smaller more manageable pieces. These pieces were analyzed about its meaning, and these meanings were

given names in the form of concepts. In other words, a detailed search for meanings that represent these concepts was done. Categories and subcategories surfaced from this process and through further analysis, smaller categories emerged which provided an overarching of the subcategories.

The following section highlights the findings of the current research project.

6.3 Findings

This section of the research paper focuses on a detailed account of the results based on the categories and subcategories that surfaced from all the data collection techniques.

6.3.1 The interviews, journal entries and field notes based on Deaf and H/H learners' interaction with the OMA

This section of the research paper covers a detailed description of the personal interviews conducted with each student as well as the journal entries from the students. Also, it describes in detail the field notes captured by the teacher-researcher using an observation schedule.

Moreover, it includes a detailed discussion of the findings of these data collection techniques as well as an analysis of the data. The section concludes with the results that emerged from further data analysis using MAXQDA, a qualitative data analysis software.

Before any discussion can commence a detailed layout of the stages, procedures and the software that was utilized to analyze the data, are presented. Table 6.1 provides a clear illustration of these elements as it was pursued in this research project based on the framework of Creswell (2014) discussed in Chapter 5.

	Stages	Procedures	Software used
1.	Data preparation	<ul style="list-style-type: none"> Transcribing the text. Data captured by the qualitative data analysis software 	Microsoft Word MAXQDA

2.	Initial exploration of data	<ul style="list-style-type: none"> Examining recurring themes and making notes 	MAXQDA
3.	Analyzing the data	<ul style="list-style-type: none"> Coding the data Grouping the codes into categories Making comparisons between categories to identify main categories and subcategories 	MAXQDA
4.	Presentation of data	<ul style="list-style-type: none"> Writing the interpretation of the findings Substantiated findings with text units Inclusion of figures and tables to highlight specific elements 	Microsoft Word Microsoft Excel
5.	Data validation	<ul style="list-style-type: none"> Methodological triangulation 	MAXQDA

Table 6.1: The stages, procedures and the software that was used during the data analysis process
[Adapted: Creswell (2014)]

A description of the steps as it unfolded within the current research project is described below.

During the interview session, Deaf and H/H learners were asked to answer questions based on their experience with the OMA. The answers to the questions were transcribed in Microsoft Word and uploaded to MAXQDA, analyzed, coded and categorized according to themes. These topics were further analyzed in search of overarching categories.

The teacher-researcher made use of an observation schedule to record field notes. The data collected from the field notes and the data from the journal entries were uploaded to MAXQDA, analyzed and linked to themes. The topics were further analyzed and categorized within MAXQDA. Figures 6.3 to 6.5 provides a detailed view of how this process evolved in MAXQDA.

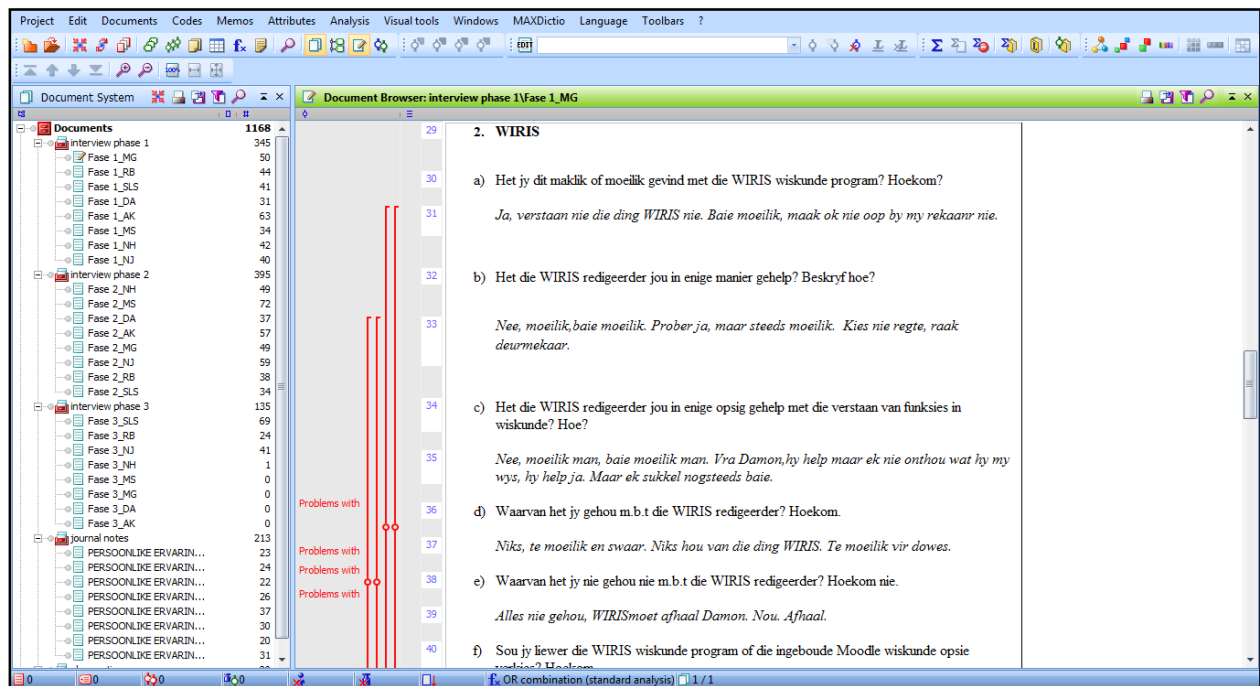


Figure 6.1: Screenshot of all the data captured in MAXQDA

Figure 6.1 provides a snapshot of all the data i.e. interview schedules, journal entries, and observation schedules, which were uploaded to MAXQDA. Each text unit was coded and further analyzed. A text unit consists of a word or a group of words identified by Deaf and H/H learners, where the group of words point to one definition. For example, “maklik, baie maklik”.

As seen from the above snapshot, the left pane provides a clear view of all the transcribed data that was uploaded. The center window presents an illustration of how the coding was done within MAXQDA.

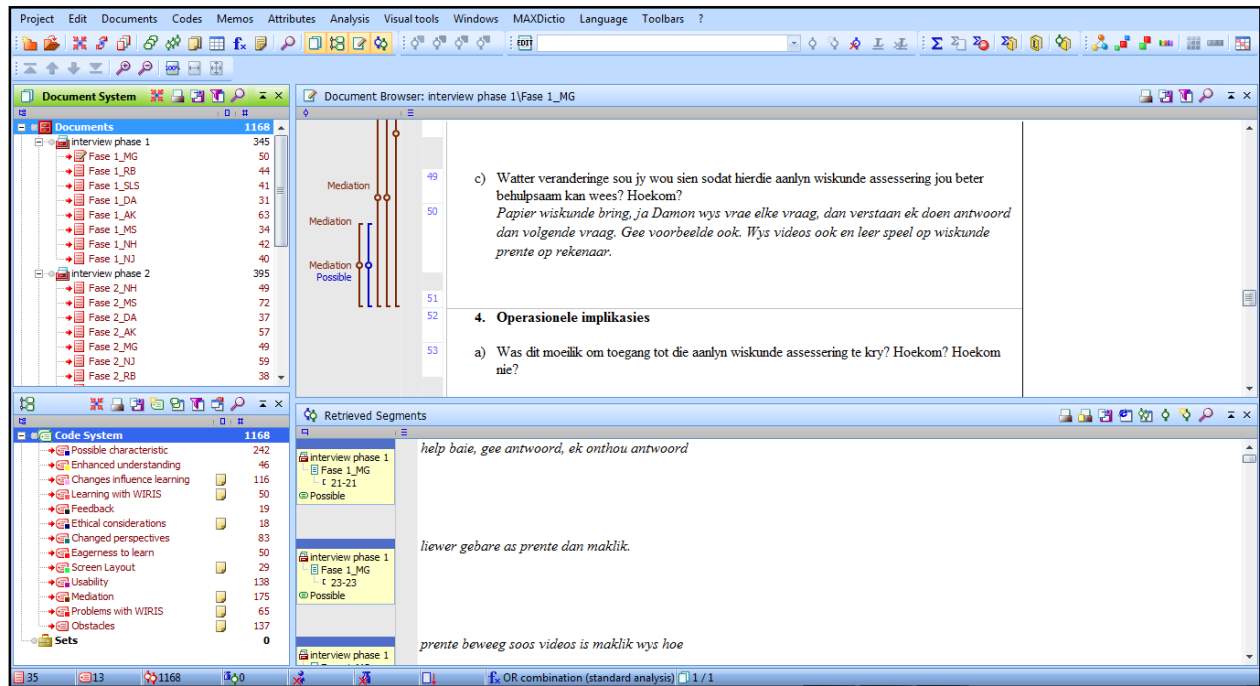


Figure 6.2: The coded segments within each document within MAXQDA

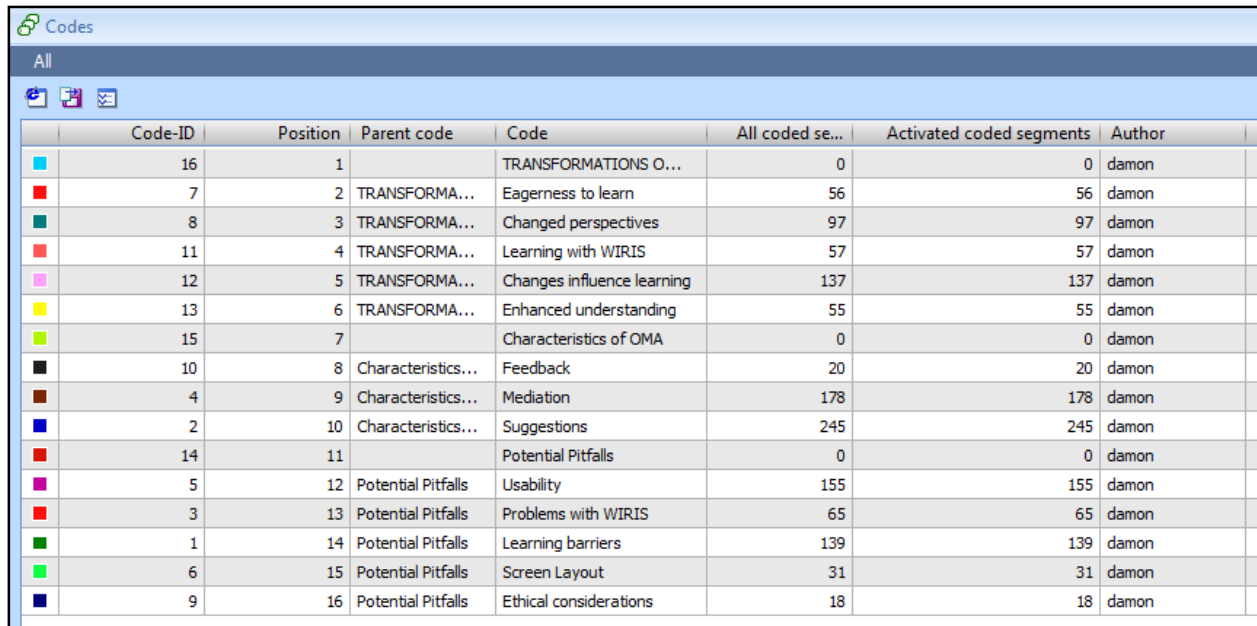
Figure 6.2 provides a detailed view of how each text unit was analyzed and coded and how the codes overlapped and as a result, new codes surfaced.

The screenshot displays the 'Code Relations Browser' window, which shows a matrix of code relationships. The matrix has 14 columns representing different codes: TRAN... (Tranformations Occur...), Eager... (Eagerness to learn), Chan... (Changed perspectives), Learn... (Learning with WIRIS), Chan... (Changes influence learning), Enha... (Enhanced understanding), Chara... (Characteristics of OMA), Feedb... (Feedback), Medi... (Mediation), Sugg... (Suggestions), Poten... (Potential Pitfalls), Usability... (Usability), Probl... (Problems with WIRIS), Learn... (Learning barriers), and Ethica... (Ethical considerations). The rows represent the same codes, with the first row being 'TRANFORMATIONS OCCUR...'. The cells in the matrix contain numerical values representing the frequency of co-occurrence between the codes. For example, the cell for 'Eagerness to learn' and 'Changed perspectives' contains the value 17.

Code System	TRAN...	Eager...	Chan...	Learn...	Chan...	Enha...	Chara...	Feedb...	Medi...	Sugg...	Poten...	Usability	Probl...	Learn...	Scee...	Ethica...
TRANFORMATIONS OCCUR...																
Eagerness to learn			17	14	16	11		7	21	19		21	10	12	10	1
Changed perspectives		17		12	16	9		13	21	23		23	11	22	12	6
Learning with WIRIS		14	12		15	11		6	19	14		13	11	5	5	2
Changes influence learning		16	16	15		14		9	18	17		18	12	13	7	1
Enhanced understanding		11	9	11	14			8	11	12		12	7	8	6	
Characteristics of OMA																
Feedback		7	13	6	9	8			9	15		10	11	11	9	4
Mediation		21	21	19	18	11		9		26		28	24	20	13	5
Suggestions		19	23	14	17	12		15	26			29	25	24	12	8
Potential Pitfalls																
Usability		21	23	13	18	12		10	28	29			18	27	17	7
Problems with WIRIS		10	11	11	12	7		11	24	25		18		16	8	8
Learning barriers		12	22	5	13	8		11	20	24		27	16		15	10
Screen Layout		10	12	5	7	6		9	13	12		17	8	15		2
Ethical considerations		1	6	2	1			4	5	8		7	8	10	2	

Figure 6.3: Code relations browser within MAXQDA

Figure 6.3 provides a detailed view of how the codes overlapped each other to make way for new categories and subcategories.



	Code-ID	Position	Parent code	Code	All coded se...	Activated coded segments	Author
	16	1		TRANSFORMATIONS O...	0	0	damon
	7	2	TRANSFORMA...	Eagerness to learn	56	56	damon
	8	3	TRANSFORMA...	Changed perspectives	97	97	damon
	11	4	TRANSFORMA...	Learning with WIRIS	57	57	damon
	12	5	TRANSFORMA...	Changes influence learning	137	137	damon
	13	6	TRANSFORMA...	Enhanced understanding	55	55	damon
	15	7		Characteristics of OMA	0	0	damon
	10	8	Characteristics...	Feedback	20	20	damon
	4	9	Characteristics...	Mediation	178	178	damon
	2	10	Characteristics...	Suggestions	245	245	damon
	14	11		Potential Pitfalls	0	0	damon
	5	12	Potential Pitfalls	Usability	155	155	damon
	3	13	Potential Pitfalls	Problems with WIRIS	65	65	damon
	1	14	Potential Pitfalls	Learning barriers	139	139	damon
	6	15	Potential Pitfalls	Screen Layout	31	31	damon
	9	16	Potential Pitfalls	Ethical considerations	18	18	damon

Figure 6.4: The code distribution in all the documents within MAXQDA

Figure 6.4 illustrates how the codes were distributed within all the documents collected for analysis. It also provides the numerical value of the coded segments. In other words, the numerical value indicates how frequently a word segments under a category or subcategory is visible within a document.

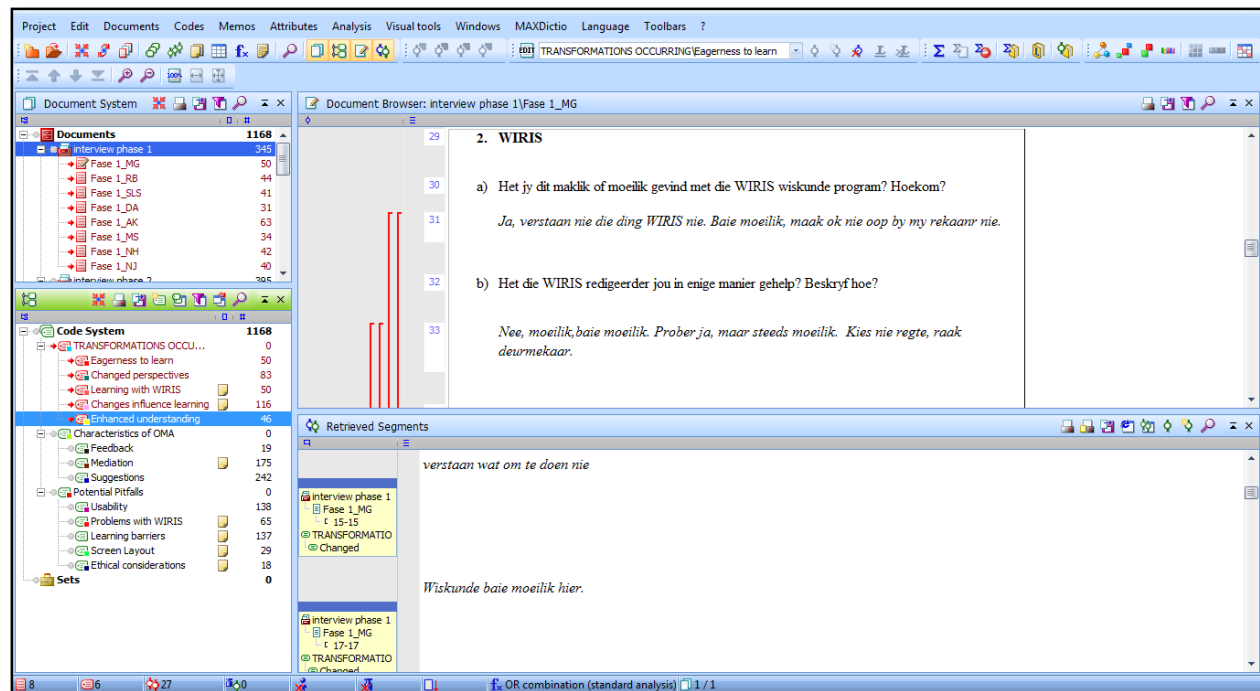


Figure 6.5: Further analysis of the text categories and subcategories in MAXQDA

Figure 6.5 illustrates how further analysis of the categories and subcategories evolved in new codes which were further categorized.

The final analysis of the categories and subcategories are illustrated in Table 6.2. A detailed discussion follows.

CATEGORY	SUB CATEGORY	TU TOTAL	TU %
Characteristics of OMA	Simplicity	55	11.13
	Learning with WIRIS	57	11.54
	Changes that influenced learning	137	27.73
	Suggestions	245	49.60
	TOTAL	494	100

Mediating the learning process	Feedback	20	5.70
	Motivation	56	15.95
	Changing perspectives	97	27.64
	Mediation	178	50.71
	TOTAL	351	100
Potential pitfalls	Ethical consideration	18	4.41
	Screen layout	31	7.60
	Problems with WIRIS	65	15.93
	Learning barriers	139	34.07
	Usability	155	37.99
	TOTAL	408	100
TOTAL TUs CODED		1253	100

Table 6.2: Categories and subcategories that emerged through analyzing the interviews, journal entries and field notes within MAXQDA

Table 6.2 above illustrates that 1253 TU were coded covering all the data collection techniques. Three categories surfaced i.e. Characteristics of OMA (494 TU), Mediating the learning process (351 TU) and Potential Pitfalls (408 TU). More importantly, these categories and subcategories surfaced through three consecutive cycles of the PAR project. In other words, not all TU were coded at once. For this reason, each cycle will be dealt with individually as the TUs per category and subcategory became noticeable. The section below will shed more light on how the categories and subcategories crystallized within each phase of this research project.

6.4 PAR cycle

The current PAR project utilized three cycles before the conclusions were drawn from the data. Each of the cycles made use of four elements of the PAR process, which include observation,

reflection, planning, and action. These elements within the PAR process were repeated three times until a conclusion was drawn. These cycles will now be discussed in detail.

6.4.1 Observation

This instance was dealt with through an informal discussion session with Grade 8 Deaf and H/H learners based on their experience with written mathematics assessment. The informal discussion consisted of a range of questions based on their experience with PPA. Similarly, the teacher researcher made use of an observation schedule to complete a variety of questions based on his observation as a teacher while learners were doing written mathematics assessments.

6.4.2 Reflection

The problem areas (both the students and the teachers') were discussed within the class with the aim of identifying the major issues and examining possible solutions to the problems. The problems that were identified by both learners, the teacher and literature studies included the following:

- too many texts,
- words are too difficult,
- fewer words and more Sign Language
- too many questions on one page,
- questions are too complex,
- no space for answers,
- more illustrations.

From the above findings, it became apparent that written mathematics assessments present certain obstacles for Deaf and H/H learners which in turn does not provide them a fair chance to demonstrate what they have learned. Accordingly, a plan was set in motion to address these obstacles.

6.5 Plan 1

Both parties discussed possible solutions to these problems such as the use of Sign Language for difficult words, the inclusion of more picture illustrations, limiting the use of text, the use of an interpreter for signing the questions, the inclusion of practice questions and the use of a computer to capture the response of learners. Also, because they were familiar with an eLearning environment, questions were raised about the possibility of doing assessments on the computer or using videos. The teacher highlighted particular dilemmas surrounding PPA such as the inclusion of too many picture illustrations would distract them and clutter the assessment. He also emphasized that video can't be used on paper and that more images mean a thicker paper to write. Both parties agreed to investigate the possibility of OMA.

6.5.1 Action

During the action cycle, the PPA were transferred to an eLearning environment, Moodle. Since the Deaf and H/H learners were accustomed to an eLearning environment (Moodle) they looked forward to doing the mathematics assessments this way.

After the questions had been transferred to the LMS, the learners were provided an opportunity to engage with the OMA. The teacher researcher kept an observation schedule and recorded the students' interaction with the OMA based on the function concept. Additionally, the pupils kept a journal to record their experience with the OMA. Moreover, the pupils were asked to participate willingly in a personal interview session with the teacher researcher. This was done through the use of semi-structured interviews.

6.5.2 Observation

An astonishing observation was made by both the teacher researcher and the learners. They all experienced difficulties with the OMA. Figure 6.6 illustrates their individual scores obtained in the OMA based on the function concept.

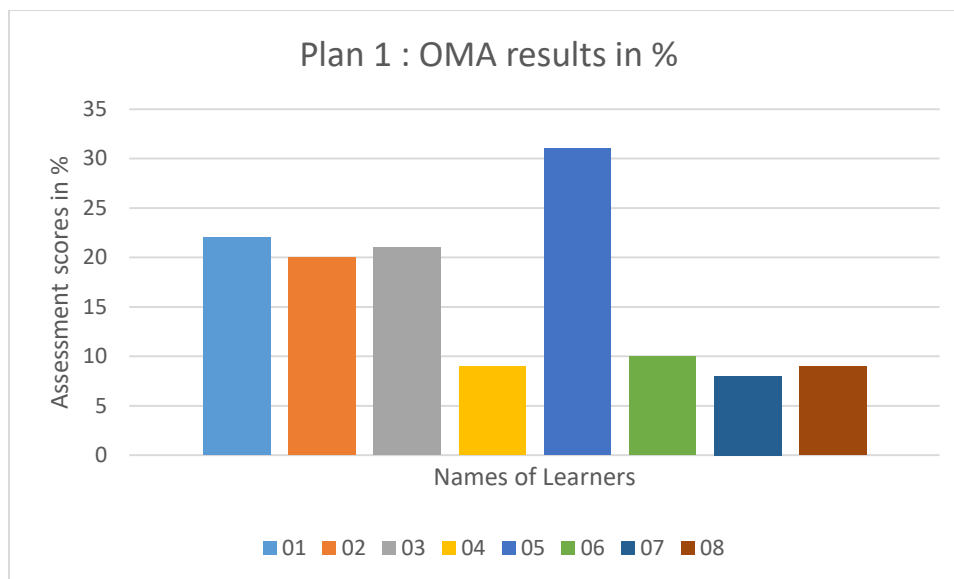
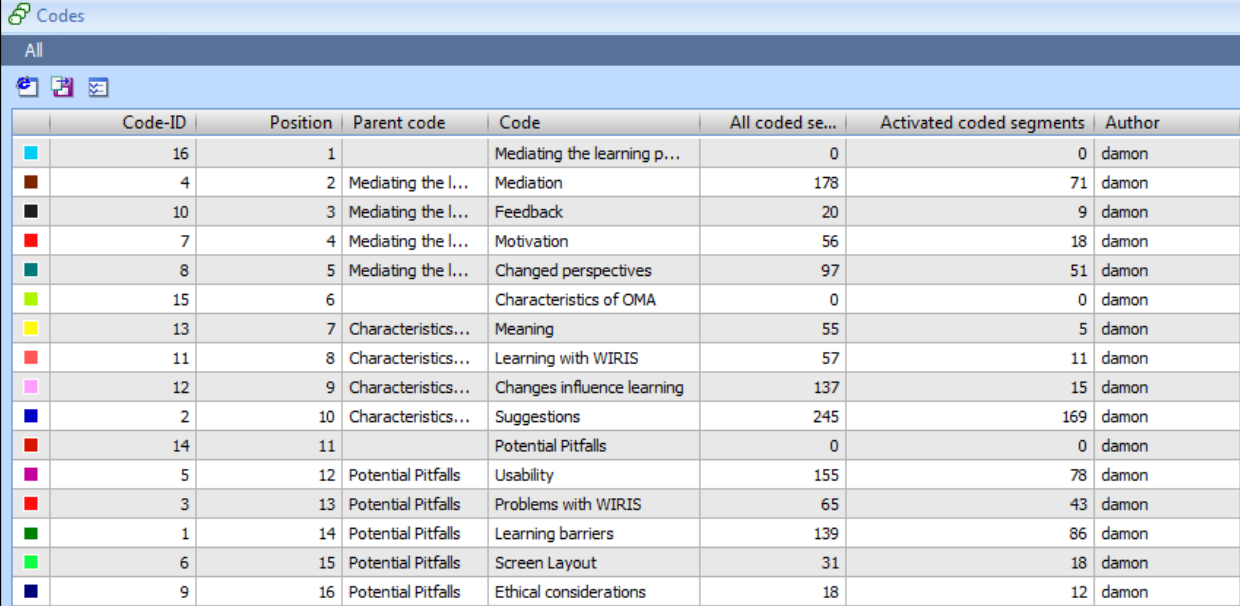


Figure 6.6: Assessment results of learners doing the OMA

As seen from Figure 6.6, no one in the Grade 8 class obtained a mark higher than 35 % for the OMA. Moreover, four learners scored less than 10% while two learners scored more than 20 %, and only one learner scored more than 30%. Since the pass mark was 50%, no one passed the OMA based on the function concept.

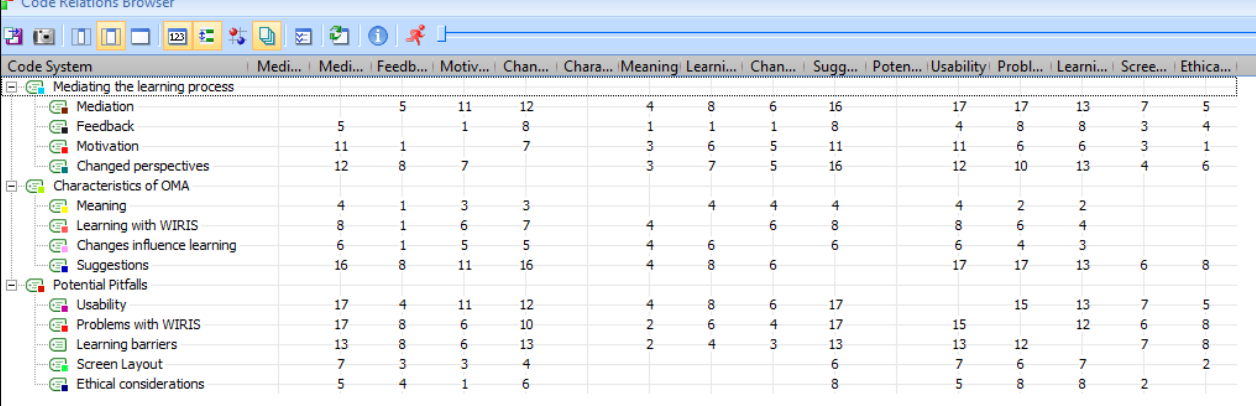
After engaging in the OMA based on the function concept, the learners were asked to partake in an interview session. The data extracted from the journal entries of each learner, together with the field notes the teachers captured in the form of an observation schedule, as well as the interview the teacher conducted with each learner, were transcribed and uploaded to MAXQDA. The text was coded and further analyzed in search of concepts and themes. Figures 6.7 and 6.8 are illustrations of the categories and subcategories that were identified within Plan 1. A detailed description follows.



	Code-ID	Position	Parent code	Code	All coded se...	Activated coded segments	Author
	16	1		Mediating the learning p...	0	0	damon
	4	2	Mediating the l...	Mediation	178	71	damon
	10	3	Mediating the l...	Feedback	20	9	damon
	7	4	Mediating the l...	Motivation	56	18	damon
	8	5	Mediating the l...	Changed perspectives	97	51	damon
	15	6		Characteristics of OMA	0	0	damon
	13	7	Characteristics...	Meaning	55	5	damon
	11	8	Characteristics...	Learning with WIRIS	57	11	damon
	12	9	Characteristics...	Changes influence learning	137	15	damon
	2	10	Characteristics...	Suggestions	245	169	damon
	14	11		Potential Pitfalls	0	0	damon
	5	12	Potential Pitfalls	Usability	155	78	damon
	3	13	Potential Pitfalls	Problems with WIRIS	65	43	damon
	1	14	Potential Pitfalls	Learning barriers	139	86	damon
	6	15	Potential Pitfalls	Screen Layout	31	18	damon
	9	16	Potential Pitfalls	Ethical considerations	18	12	damon

Figure 6.7: TU of plan one as coded in MAXQDA

The figure above provides an illustration of the color coded text segments with its overarching themes.



Code System	Medi...	Medi...	Feedb...	Motiv...	Chan...	Chara...	Meaning	Learni...	Chan...	Sugg...	Poten...	Usability	Probl...	Learni...	Scre...	Ethica...
Mediating the learning process																
Mediation			5	11	12		4	8	6	16		17	17	13	7	5
Feedback		5		1	8		1	1	1	8		4	8	8	3	4
Motivation		11	1		7		3	6	5	11		11	6	6	3	1
Changed perspectives		12	8	7			3	7	5	16		12	10	13	4	6
Characteristics of OMA																
Meaning		4	1	3	3			4	4	4		4	2	2		
Learning with WIRIS		8	1	6	7		4		6	8		8	6	4		
Changes influence learning		6	1	5	5		4	6		6		6	4	3		
Suggestions		16	8	11	16		4	8	6			17	17	13	6	8
Potential Pitfalls																
Usability		17	4	11	12		4	8	6	17			15	13	7	5
Problems with WIRIS		17	8	6	10		2	6	4	17		15		12	6	8
Learning barriers		13	8	6	13		2	4	3	13		13	12		7	8
Screen Layout		7	3	3	4					6		7	6	7		2
Ethical considerations		5	4	1	6					8		5	8	8	2	

Figure 6.8: Code relation browser within MAXQDA

The figure above provides a clear picture of the frequency of each text unit and how it is connected to other text units within other themes.

The table below provides a detailed illustration of the categories and subcategories that surfaced in Plan 1. An analysis of Table 6.3 follows.

CATEGORY	SUB CATEGORY	TU TOTAL	TU %
Characteristics of OMA	Simplicity	5	2.5
	Learning with WIRIS	11	5.5
	Changes that influenced learning	15	7.5
	Suggestions	169	84.5
	TOTAL	200	100
Mediating the learning process	Feedback	9	6.04
	Motivation	18	12.08
	Changing perspectives	51	34.23
	Mediation	71	47.65
	TOTAL	149	100
Potential pitfalls	Ethical consideration	12	5.06
	Screen layout	18	7.60
	Problems with WIRIS	43	18.14
	Learning barriers	86	36.29
	Usability	78	32.91
	TOTAL	237	100
TOTAL TUs CODED		586	100

Table 6.3: The categories and subcategories identified within MAXQDA for Plan 1

6.6 Findings based on the interviews, journal entries and field notes based on Plan 1

Table 6.3 is an illustration of the categories and subcategories that surfaced during the data analysis process depicted by figures 6.7 and 6.8. It illustrates that a total of 586 TU were coded of which 200 TU are related to the ‘*Characteristics of OMA*,’ 149 TU related to ‘*Mediating the*

learning process’ and 237 TU related to ‘*Potential pitfalls.*’ Further analysis of the answers learners provided indicates that the OMA had major pitfalls which influenced the learning process negatively. Not only did the answers from the Deaf and H/H students raise some ethical concerns (12 TU) but it also shed light on usability issues (78 TU), barriers to learning elements (86 TU) and major problems experienced with WIRIS (43 TU). Furthermore, their answers also included 169 TU (84.5 %) based on suggestions Deaf, and H/H learners had concerning the format of the OMA. Each category will now be discussed in detail.

6.6.1 Category 1: Characteristics of OMA

From the data in Table 6.3, it can be noted that within ‘*Characteristics of OMA*’ category, 200 TU were coded. Moreover, the participants’ answers included the subcategories ‘Simplicity’ 5 TU (2.5%), ‘Learning with WIRIS’ 11 TU (5.5%), ‘Changes that influenced learning’ 15 TU (7.5%) and ‘Suggestions’ 169 TU (84.5%) irrespectively. Each of these subcategories will now be described.

6.6.1.1 Simplicity

Simplicity refers to a lack of difficulty or hardness. The field notes and the answers from learners highlighted that they found it difficult to comprehend what to do while engaging in the OMA. Comments such as “too difficult”, too hard, don’t understand and don’t know what to do are all indications that Deaf and H/H learners experienced significant difficulties with the OMA.

Both the subcategories ‘learning with WIRIS’ and ‘changes that influenced learning’ indicates a low TU count because no changes were made yet and help was provided with WIRIS by the teacher-researcher.

6.6.1.2 Suggestions

The Suggestion subcategory consisted of 169 TU (84.5%), and it dominated the category, characteristics of OMA. This subcategory surfaced by providing users a chance to comment on aspects in need of change and inclusion in the OMA. It is also a result of the obstacles users experienced with elements in the OMA. These suggestions included items such as long, complex sentences should be replaced by Sign Language, the inclusion of more interactive content, more help within the OMA and step by step examples. These elements will now be discussed below.

6.6.1.3 Long, complex sentences should be replaced by Sign Language

All the users had trouble interpreting the long questions, and they suggested that shorter sentences be used. Also, they comment on the inclusion of more images as well as Sign Language. Some of them went as far as to suggest the elimination of the sentences and only include Sign Language while other suggest that fewer elements should be visible on the page i.e. only the question and image/video. These are some of the comments extracted from the interviews and journal entries: “*hoekom nie net vraag en prent en miskien video of help, lang sinne haal uit, wys net sommige woorde en prente baie (user RB); Min sinne op blad en meer prente, gebare wys my hoe met videos dan sien ek hoe (user SLS); liewer gebare dan verstaan ek, nie die lang vrae, (user DA); sinne lank, te veel woorde, moeilike woorde verstaan nie, (user AK)*”.

6.6.1.4 The inclusion of more interactive content

Users continually complain about the inclusion of too many texts and suggested that more interactive content such as videos, interactive activities like GeoGebra and more images should be included in the OMA. They also suggested that video tutorials be included in the feedback for them to learn from it. This became noticeable through their answers to the question: “*watter veranderinge sou jy wou aanbring?*” (Which changes would you bring about if you had the

chance?). Their suggestions included: “*prente, videos, gebare en speletjies, prente beweeg soos videos is maklik wys hoe* (user MG); *Baie prente, gebare baie, videos met voorbeelde help baie* (user RB); *meer videos met gebare, gebare baie* (user SLS); *te min prente man wys liewer videos, baie voorbeelde, prente, videos baie* (user DA).

6.6.1.5 More help

All the users suggested that more assistance should be made available to them in the OMA. Their motivation lies in their view that when they got stuck on a question, help should be in reach within the OMA. Moreover, help should be in the format of either video tutorials or worked out examples. Their suggestions included the following: “*help is ja dan miskien hou van rekenaar wiskunde* (user RB); *Ja, help my, voorbeelde help ook* (user SLS); *Meer help vir my asseblief*, (user DA); *Help nodig* (user AK)”.

6.6.1.6 Step by step guides

Users also suggested that step by step examples should be included in the OMA. In other words, they needed instances in the form of worked-out exercises to follow to strengthen their understanding surrounding the function concept before moving to a new concept. This surfaced through their responses such as: “*wys my hoe stap vir stap en hou wys my hoe daar op rekenaar dan ek elke keer kyk as ek sukkel* (user RB); *voorbeelde help ook, Baie voorbeelde en videos help my* (user SLS); *Wys hoe dan weet ek miskien, eerste voorbeeld en dan vraag om te doen*, (user DA); *Wys my hoe, dan sal makliker wees* (user AK)”.

Category 2: Mediating the learning process will now be discussed.

6.6.2 Category 2: Mediating the learning process

From the data in Table 6.3, it can be noted that within ‘*Mediating the learning process*’ category 149 TU were coded. Moreover, the participants’ answers included the subcategories ‘*Feedback*’ 9 TU (56.04%), ‘*Motivation*’ 18 TU (12.08%), ‘*Changing perspectives*’ 51 TU (34.23%) and ‘*Mediation*’ 71 TU (47.65%). Each of these subcategories will now be described.

6.6.2.1 Feedback

Before the findings on feedback can be presented it should be noted here that feedback was only provided to users while they were doing the OMA in practice mode and not in exam mode. During Plan 1 of the PAR process, feedback was given by providing users with only the correct answer. In other words, when users typed in or selected the correct answer, the feedback they were presented with only displayed the right answer or a red ‘x’ for the wrong answer. This made it possible for users to memorize the answers or write the answers down on a piece of paper for later use. Not only did this create validity issues but users weren’t given the opportunity to learn from their mistakes by providing them with useful feedback. These findings became visible through detailed analysis of users’ answers such as: “*ja, regte antwoord gehelp. Onthou regte antwoord (user DA); wys lekker regte antwoord. (user NH); Ja wys regte antwoorde, probeer onthou (user AK)*”.

6.6.2.2 Feedback resolved

A decision was made to provide general and specific feedback on each question to deliver feedback that is more effective and useful. In the case of general or overall feedback, it includes giving feedback when users answered the question correctly. This feedback usually provides comments such as: ‘well done’, ‘congratulations’, ‘keep it up’, etc. It is more or less encouragement for the next question. Specific feedback, on the other hand, includes a breakdown of the correct answer. In other words, not just the right answer but a step by step guide to showcase how the solution was obtained.

A further modification to the feedback feature, starting from Plan 2, was to provide video simulations of similar problems based on the function concept. For example, when users answered a question wrong, they are presented with a similar problem which they can learn from. Figure 6.9 is an illustration of the video feedback feature utilized in Plan 2 and Plan 3.

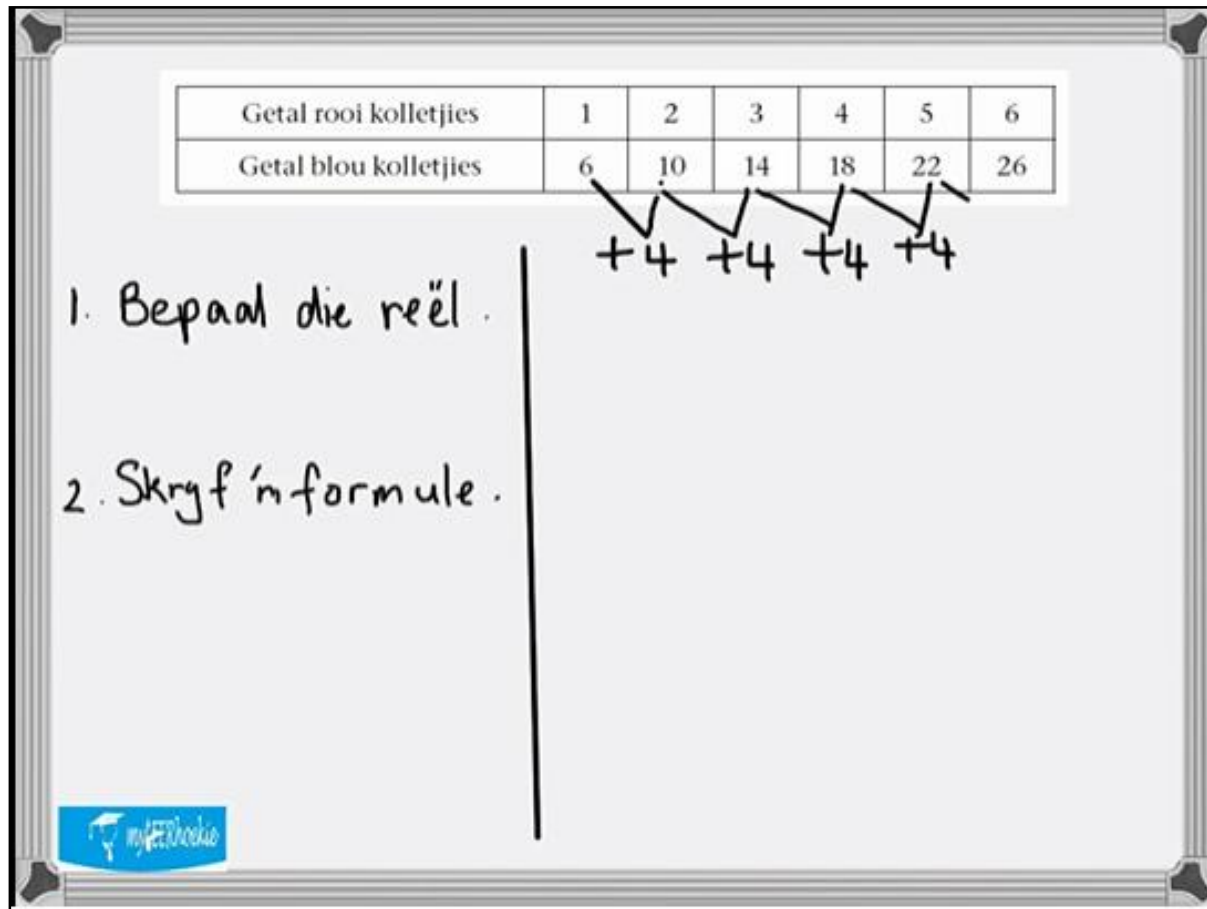


Figure 6.9: An example of the video feedback within the OMA

This video feedback feature was very effective since users obtaining a wrong answer could watch the video tutorial on the function concept and gain a better understanding. Not only did this feature assist Deaf and H/H learners with understanding the function concept better, but they could learn from the mistakes they made in previous attempts.

6.6.2.3 Motivation

The subcategory ‘motivation’ consisted of 18 TU (12.08%) that were coded from the users’ answers in the interview sessions and journal entries. It also included TU from the field notes the teacher researcher captured. During the first Plan, learners weren’t motivated enough to participate in the OMA. This became visible in the answers they provided in which indicated that they need to practice the skills necessary for the OMA. Also, they complained that except for the mathematics class, there was no other place at school to practice the tests and that they would appreciate it if they had opportunities to practice at home or at their respective hostel accommodations (*‘huis oefen program dan sal nie meer sukkel,’ user MG*). They also indicated that if they understood WIRIS, they would do better on the tests (*‘leer my WIRIS dan wiskunde verstaan man,’ user SLS*).

6.6.2.4 Changing perspectives

This subcategory had 51 TU (34.23%) that were coded from the users’ answers. Changing perspectives includes users’ perspectives regarding the OMA based on functions. During Plan 1 all of the users had a negative perspective regarding the OMA. Their answers included comments such as user MG *“baie moeilik, verstaan wat om te doen nie, moeilik en swaar, help niks om te verstaan”*; user RB *“swaar die wiskunde baie swaar, rekenaar wiskunde, baie moeilik”*; user SLS *“net swaarder gemaak, ek verstaan nie”*; user AK *“swaar, moeilik, sukkel, rekenaar wiskunde swaar”*; user NJ *“was nie lus vir Wiskunde nie, moeilik”*. In other words, while some complain how they don’t like OMA, others comment on how difficult it was to understand. Therefore, one can acknowledge that the first encounter learners had with the OMA weren’t very optimistic.

6.6.2.5 Mediation

Mediation refers to the way in which the OMA or the teacher researcher intervened to make the learning process more meaningful for each user. Within the subcategory, ‘Mediation’ 71 TU

(47.65%) were coded. From the answers extracted from the interviews, journal entries and field notes it became visible that there were little to no help provided to users within the OMA. Users were continually seeking some form of assistance, but there were none. Since users were struggling to complete the OMA, they felt that some support should be given to help them with each question in the OMA. At first, users assert that they need help, then they added that the questions were too difficult, and assistance is required in the form of either video (user NH: “*Meer videos vir help*”) or examples (user NH: “*baie voorbeelde vir my wys hoe*”). Moreover, it also became visible when participant submitted incomplete quizzes. When asked why they did that they replied: “*verstaan nie, weet nie, baie swaar.*”

Category 3: Potential pitfalls will now be discussed.

6.6.3 Category 3: Potential pitfalls

Category 3 was named Potential pitfalls and included all the TU that relate to obstacles Deaf and H/H learners experience while doing the OMA. Within the ‘*Potential pitfalls*’ category, 237 TU were coded. In other words, 237 TU relating to obstacles Deaf and H/H learners experience while doing the OMA were recorded via the personal interviews, journal entries, and field notes. Moreover, the participants’ answers included the subcategories ‘Usability 78 TU (32.91%) and ‘Learning barriers’ 86 TU (36.29%) irrespectively. It also included subcategories such as ‘Problems with WIRIS’ 43 TU (18.14%), ‘Screen layout’ 18 TU (7.60%) and ‘Ethical considerations’ 12 TU (5.06%). Each of these subcategories will now be described.

6.6.3.1 Ethical considerations

The first cycle of the PAR project raised different validity issues which had to be dealt with in subsequent cycles to guarantee the trustworthiness of the current research project. For example, during the interviews held with all the participants, user MG concluded: “*gee antwoord, ek onthou antwoord*” (provide the answer, I will memorize the answer). User RB also shared this answer “*ek kan antwoorde onthou en neerskryf en gebruik vir volgende toets*” (I can memorize

and use the answer for the next test), user NJ “*onthou vir later*” (remember for later use) while user NH responded: “*skryf antwoord neer.*” Further analysis of these sentences reveals that these users were used to memorizing answers instead of gaining a conceptual understanding of the problem. The OMA provided space for learners to memorize answers instead of providing them opportunities to practice understanding and skills. Also, user DA’s answer: ‘*kyk somme hulle antwoorde*’ (look at my classmates’ response) and user AK’s answer: ‘*kyk by maats*’ (look at my classmates’ answers) and also in DA’s journal notes i.e. ‘*kyk somme hulle antwoorde*’ (look at my classmates’ answers) is an indication that the validity of the OMA could be compromised.

The field notes recorded, further, strengthens the view that the validity of the OMA could compromise the inferences being drawn from the research results. For example, the teacher researcher noted that ‘*they started making notes*’; ‘*try to write the answers on a piece of paper*’ and ‘*making notes with the correct answers.*’ Moreover, the teacher researcher also pointed out that they ‘*started signing the answers to each other*’; ‘*used Moodle’s messaging service to ask for answers*’ and ‘*looked at their classmates’ answers.*’

The teacher researcher, as well as the participants, had to come up with solutions to eliminate any issues that could disrepute the credibility of the outcomes of the research study.

6.6.3.2 Screen layout

The screen layout also presented learners with some difficulties in accessing the main content of the OMA. Most of the learners complain that too much information was displayed on one page. Moreover, they suggested that less information on one page might be less distracting. They also complained that there were too many questions on one page. This became apparent in participant’s answers such as, user MG responded: ‘*klomp prente en woorde opskerm, langs kant engels, verstaan nie*’, ‘*deurmekaar weet nie waar ek is en wat soek ek*’ and ‘*baie goeters op skerm, maak my mal*’; user RB answered: ‘*heeltyd deurmekeer*’, ‘*dan hie kyk dan daa kyk, weetie wat op kyk nie*’ and ‘*baie goed langs kant en bo en onder, te veel,haal weg*’ and user SLS answered: ‘*te baie langs kant en onder, maak my mal, soek soek maar deurmekeer*’, ‘*baie op skerm*’.

As for the journal notes of MG, it stated: *'klomp prente en woorde op skerm.'* On the other hand, user AK suggests that less words and pictures and one question per page could be a solution (*minder woorde en prente op een blad.*). These issues had to be addressed to provide learners fair access to the OMA and to eliminate any obstacles the OMA might present. For this reason, certain modification needed to be set in place to ensure that no distraction was visible that could impinge on learners answering the questions.

6.6.3.3 Problems with WIRIS

Problems with WIRIS included 43 TU (18.14%). It relates to problems users experienced while engaging with WIRIS. All the users had difficulties with WIRIS. These challenges included: loading WIRIS, using WIRIS and learning from WIRIS. The obstacles WIRIS presented became apparent from the variety of answers from the users. User MG replied *'verstaan nie die ding WIRIS', 'moeilik, baie moeilik'*; user RB answered *'sukkel net met dit', 'WIRIS, maak wiskunde swaar'*; user SLS answered *'sukkel met WIRIS, moeilik', 'niks van gehou nie, sukkel man, help my met die WIRIS'*; user DA explained *'moeilik sukkel te veel'* and user MS answered *'kyk waar kliek en wanneer in antwoord spring, wag wag wanneer in antwoord spring, maak toe dan weg'*

Other answers included: *'rekenaar wil nie WIRIS wys', 'WIRIS nie oopmaak nie'*; user NJ answered *'Wiris nie oopmaak sukkel by rekenaar.'* On the other hand, user RB concluded: *'min tyd met wiris en somer gou leer'* and *'kanie gou leer nie ek moet probeer en probeer en probeer lang tyd.'*

From the above answers, one can deduce that the users struggled with WIRIS. On the contrary, they had difficulties using WIRIS and WIRIS wouldn't load efficiently. Also, learners complained that the time spend to become accustomed to WIRIS was not enough. To improve the learners' experience with WIRIS, it was decided to make certain modifications.

6.6.3.4 Learning barriers

The subcategory ‘*Learning barriers*’ included 86 TU (36.29%). It is the subcategory for difficulties users experience with reading, interpretation, and comprehension. These elements presented learners with barriers to learning and were mainly identified by all learners. For example, user MG asserts that it’s hard to read the questions and that questions without Sign Language are difficult to interpret for the Deaf. This user also posits that the words within the questions were too much and that unfamiliar words are present. This user’s answers included: ‘*vrae sonder gebare baie moeilik*’, ‘*woorde is moeilik met vrae*’, ‘*sukkel nog baie om vrae te lees, te veel woorde vir my, ek verstaan nie lekker woorde*’.

User DA shares in this view by complaining that the questions are too long and that sentences without Sign Language are tough for Deaf learners. This view is also in line with user AK’s view that Sign Language is needed for every question and that the words within the questions don’t make any sense. User AK’s answers included: ‘*woorde te veel*’, ‘*waar is gebare dan*’, ‘*sukkel om woorde te verstaan*’. User MS’s contribution points to questions that include too many words and that the sentences are too long to grasp (*vrae baie lang sinne, baie woorde*). This user further indicated that the time for the OMA is not enough and that more time should be added (*tyd min*).

User, NJ raised another issue by indicating that the longer the sentence, the more concentration is needed, and the more attention should be used to determine relevant information (*baie lees en kyk wat belangrik*). User SLS shares in this view by indicating that too many words confuse the Deaf learners and creates difficulties in comprehension (*deurmekaar met baie woorde ek sukkel met woorde verstaan*).

The field notes of the teacher-researcher, as well as the journal entries from the learners, also revealed similarities. For example, the teacher researcher pointed out that users struggled to grasp unfamiliar words, and it led to learners misinterpreting the questions. Also, users had difficulties interpreting multi-part questions without a clear indication that one image should be used for all the questions. What became apparent was the fact that all the users had trouble interpreting the questions when there was no Sign Language present. Also, reading became a

major problem and learners were continually asking for the meaning of words. Additionally, users couldn't answer questions when higher order thinking was needed. A common occurrence among all learners was that they wanted a signed representation of all the question as well.

In sum, the following difficulties were experienced by the learners while doing the OMA based on the function concept. Table 6.4 illustrates these challenges.

No	Learning barriers	Cycle 1
1.	Written translation of questions	Learners experience difficulties with Afrikaans translations.
2.	Familiar and unfamiliar words	Learners experienced difficulties identifying familiar and unfamiliar words.
3.	Sentences are too complex	Learners complain that sentences were too long which made it difficult to follow and therefore hard to understand.
4.	Reading difficulties	They had trouble reading long questions and identifying awkward words
5.	Interpretation problems	Learners experienced difficulties interpreting text and illustration based problems.
6.	Higher order thinking skills	When problems became challenging, they could not master it, left it blank or got it wrong.

Table 6.4: The measures that were implemented to minimize the learning barriers

As illustrated by Table 6.4 Deaf and H/H learners had significant difficulties with written text and struggled to read, comprehend and interpret written text. The more complicated the text became, the more difficult it was to provide answers to the text (questions). Therefore, one can adopt the perspective that Deaf and H/H learners were presented with unfair practices since their barriers became an obstacle in their learning processes and hence it was directly in contrast to these learners' human rights of fair access to teaching and learning.

6.6.3.5 Usability

The subcategory ‘*Usability*’ included 78 TU (32.91%) and therefore an indication that users experienced a lot of difficulties in this area. Essentially, the two most prominent usability issues included 1) Load shedding and 2) internet issues.

6.6.3.5.1 Load shedding

Load shedding became a major problem since it denied users access to computers due to power shortages. Load shedding also resulted in no internet access. In other words, due to load shedding the OMA could not run let alone be accessed? Accordingly, a strict program, considering Eskom’s load shedding schedule, had to be set in place to accommodate electricity time out.

6.6.3.5.2 Internet issues

Along with load shedding issues were trouble with internet access. Since the OMA is web based, problems with internet access directly influenced access to the OMA. Since the school experienced load shedding, it affected the internet access. For example, times scheduled for load shedding increased problems with internet access. Moreover, even when no load shedding occurred we also experienced internet problems. For some parts of the day, usually in the morning, the internet is very slow, so this had to be taken into consideration.

Both these issues had a huge impact on the usability of the computers and thus the OMA. Moreover, it also had an adverse influence on the users’ emotions. This became apparent based on the answers they presented. These responses indicated that users were frustrated and furious for both the load shedding and the internet problems.

Apart from the two issues described above another concerning usability issues was access to the OMA. Users had great difficulties with the login process. Since Moodle requires a secure password which must consist of “at least eight characters and contain at least one number, at least one lowercase letter, at least one uppercase letter and at least one non-alphanumeric character” (Moodle, 2016). They complained that the password needed were too difficult to remember. Moreover, they took the option of the web browser to remember the password which

created security issues, since any learners typing in the first letter of their names could be presented with full access to their accounts.

All of the users (100%) also assert that the web address was too difficult to remember and that they could not access the OMA when they had to enter the web address themselves. So, both these issues i.e. log in difficulties and users remembering the web address had to be rectified.

6.7 Reflection (interpret the findings)

From the above results, it became apparent that a lot had to be done to improve users' experience with the OMA for it to assist them with their understanding of the function concept.

Accordingly, the following was found within each of the main categories:

6.7.1 Characteristics of OMA

- More Sign Language should be utilized;
- More examples should be included;
- More interactive content should be used;
- Video tutorials or video lessons should be incorporated within each question;
- Feedback should be more meaningful by including video examples to learn from;
- Step by step guides should also be included.

6.7.2 Mediating the learning process

- No help was provided within the OMA except the teacher;
- Although the OMA was supposed to increase understanding it made understanding the function concept more difficult;
- More assistance was needed within the OMA

6.7.3 Potential pitfalls

- too much text and thus too much reading and interpretation to do;
- not enough Sign Language or signed words;
- too static i.e. learners only have to choose between the correct and wrong answers;
- too many questions that were visible on one page;
- screen layout problems;
- feedback too simplistic i.e. only the correct/incorrect answer;
- Learners experienced usability issues regarding the OMA;
- WIRIS usability issues;
- Validity issues

After acknowledging the above problems learners experience with the OMA, both parties agreed that adjustments had to be made to the OMA to be meaningful and not just a representation of the PPA. For this reason, Plan 2 was put in place.

6.8 Plan 2

The goal of Plan 2 was to rectify or improve the difficulties users experienced during Plan 1. This was done by analyzing all the problems users experienced in their first encounter with the OMA. Also, utilizing the ideas of users included in the suggestion subcategory, hence giving meaning and ownership to the OMA. However, just adding new content or modifying existing content without utilizing a particular framework might have brought about the same results as with Plan 1. Therefore, an in-depth literature review was conducted in search of a framework to encapsulate possible solutions to specific problems users experienced.

Taken into consideration all the obstacles that surfaced during Plan 1 it was necessary to devise a modified plan to address these barriers. For this reason, it was decided to utilize the seven principles of the Universal Designed Assessment (UDA) proposed by Thompson, Johnstone, and Thurlow (2002). These seven principles will now be discussed and how the OMA based on the function concept was constructed in line with the UDA principles.

6.8.1 The Universal Designed Assessment (UDA)

The UDA are assessments designed and developed to provide access to all participants irrespective of their disabilities (Thurlow, Lazarus, Albus & Hodgson, 2010). It is based on the principles of universal design developed by the Centre for Universal Design (Centre for Universal Design, 1997) with the aim of guiding role-players in the design of environments and other products (Thompson, Thurlow & Malouf, 2004). In other words, the goal of these principles is to provide a floorplan for the design of a more accessible environment or product, in this case, available OMA for Deaf and H/H learners. A further aim is also to ensure that valid inferences be drawn from the assessment results and that it is in line with curriculum standards, in this case, CAPS. Hence the focus is on an inclusive evaluation system, one in which every learner can participate in. The seven principles include:

- “Inclusive assessment population
- Precisely defined constructs
- Accessible, non-biased items
- Amendable to accommodations
- Simple, clear and intuitive instructions and procedures
- Maximum readability and comprehensibility
- Maximum legibility” (Thompson, Johnstone & Thurlow, 2002:6).

Each of these seven principles guided the construction of the OMA. Also, visible elements related to these principles were identified, and modifications to the current OMA in line with the UDA were made. Moreover, challenges based on the use of the UDA will be highlighted.

The next section describes the UDA principles.

6.8.1.1 *Inclusive assessment population*

Every test should be developed keeping in mind the population for which it is designed for (Thompson, Johnstone & Thurlow, 2002; Thompson, Thurlow & Malouf, 2004). Accordingly, if the test is developed for school-based assessment purposes, it should include all learners participating in school-based assessments. Only students with severe cognitive disabilities that

are in need of other forms of assessment accommodation or alternate assessment should be excluded.

The OMA was designed for SBA and specifically Deaf and H/H learners. However, these OMA is also accessible for students with learning disabilities as well as hearing learners. In other words, the OMA is in line with the function concepts prescribed by CAPS (DoE, 2011) and therefore in line with curriculum standards.

6.8.1.2 Precisely defined constructs

This principle implies that the assessment should measure what it was designed to measure (Thompson, Thurlow & Malouf, 2004). Therefore, before the assessment is developed, the test administrator should identify what should be assessed and then create opportunities within the test to evaluate only those outcomes that were identified. Thompson, Thurlow & Malouf (2004) argue that UDA should “remove all construct irrelevant cognitive, sensory, emotional and physical barriers” the assessment presents (p.6).

The OMA includes content related to the function concept prescribed by CAPS (DoE, 2011). Therefore, the OMA tested items related to the function concept which includes the function machine, formulae and representations of the function concept through the use of tables, graphs, and text. Since obstacles were already identified in Plan 1 such as long, complex sentences, unfamiliar words, etc., these obstacles were addressed within this cycle.

6.8.1.3 Accessible, non-biased items

This principle relates to the scrutinizing of test questions with the aim of eliminating insensitivity towards physically challenged participants (Thompson, Thurlow & Malouf, 2004). Also, it presupposes test items are created by test designers who are familiar with the population it is aimed at. More importantly, the underlying principle of tests is accessibility which means that it forms the cornerstone of each test item.

This principle was achieved and maintained by providing alternative illustrations or videos in the form of Sign Language. Since the target population was Deaf and H/H learners who are

dependent on Sign Language, it was necessary to design the test items according to their needs. However, the OMA can also be utilized by learners with learning disabilities as well as hearing students.

6.8.1.4 Amendable to accommodations

Although the aim of UDA is accessibility, some test items may require additional accommodation for some students. Therefore, this principle creates space for the incorporation of other forms of accommodation, if the need exists. For example, in the case of Deaf and H/H learners where written text creates barriers to learning, utilizing signed representations or other formats to overcome these obstacles are incorporated within this principle.

Since the participants in this study are Deaf and H/H, written text presents a huge obstacle. For this reason, the OMA was used in conjunction with a glossary. Essentially this means that certain concepts or words are linked to a glossary which learners could click on. When students clicked on these highlighted words or ideas, they are presented with a signed explanation of the word or concept. Figure 6.10 illustrates how this principle was achieved in this research project.

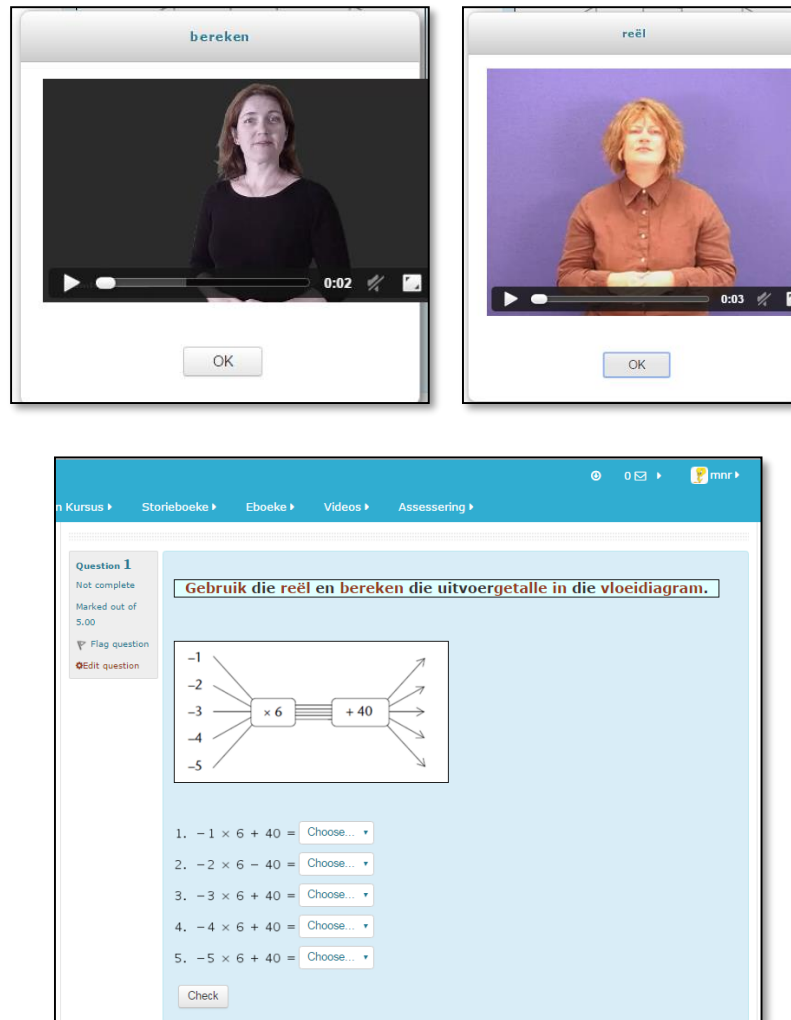


Figure 6.10: How the principle of amenable to accommodation was obtained in this research project

As seen from the above illustration words like ‘reël,’ ‘bereken’ and ‘vloeidiagram’ are highlighted which indicate that it is linked to a glossary. When learners click on the highlighted words, a popup appears with a signed description of the term.

6.8.1.5 Simple, clear and intuitive instructions and procedures

Questions within tests should be clearly stated for each learner irrespective of “experience, knowledge, language skills or current concentration level” (Thompson, Thurlow & Malouf, 2004:7) to comprehend. Essentially this means that the questions within the assessment should

be unambiguous and therefore should not create any misunderstanding while interpreting it. Since this was the case within Plan 1, modifications needed to be made to the OMA.

The use of simple, clear and intuitive instructions and procedures were preserved in this research study through the use of Sign Language. Since Sign Language is made up of gestures, placement, and expressions, fewer words are used. Although a written form of the question was displayed, Deaf and H/H learners had access to the signed version of the question, which is straightforward and clear.

6.8.1.6 Maximum readability and comprehensibility

Text within assessment items should be easily readable and comprehensible. Gaster and Clark (1995) provides a comprehensive guide in making text items more accessible to all learners irrespective of their learning disabilities. For this reason, they proposed Plain Language for instruction and assessment. “Plain Language is text-based language that is straightforward, concise and uses everyday words to convey meaning. The goal of Plain Language editing strategies is to improve the comprehensibility of written text while preserving the essence of its message. Greater clarity may be achieved, for instance, by reducing text length, removing esoteric jargon, and adding illustrations to aid the reader in her understanding of written information” (Hanson, Hayes, Schriver, LeMahieu, and Brown, 1998:2-3 in Brown, 1999:3). Kiplinger, Haug, and Abedi (2000) agree with this view and posit that mathematics proficiency in learners decreased when students experienced difficulties with language. On the other hand, when students were presented with simple terms, their ability improved.

Maximum readability and comprehensibility were maintained within Plan 2 by giving attention to the following:

Strategy	Example within this research project
Reduce excessive length	The use of simple sentences and therefore eliminating unnecessary items.
Use common words	Using words or phrases that are familiar to Deaf and H/H learners. Also, providing signs for words.

Avoid ambiguous words	Eliminating words or phrases that can cause confusion to learners. Also, offering signs for words
Avoid irregular spelled words	Focus on words that are part of the Deaf and H/H learners' everyday vocabulary.
Avoid proper names	Encourage the use of first names instead of proper names
Avoid inconsistent naming and graphic conventions	Not using words or phrases interchangeably. Only use one name for a particular concept in conjunction with the signed word.
Avoid unclear signals about how to direct attention	Provide clear descriptions of what is about to happen or what the learners should do next.
Mark all questions	Provide an indication that this is a question or that learners should give attention to some concepts.

Table 6.5: Maximum readability and comprehensibility maintained in the current research study
[Adapted: Brown, 1999:4]

A point that needs to be taken into consideration is that the original mathematics terms and concepts were retained. However, the concepts and terms were linked to a glossary which provided either a description in Sign Language or an example of the concept or term as a means of explanation.

6.8.1.7 Maximum Legibility

Legibility, according to Thompson, Thurlow & Malouf (2004) refers to the physical format of the text or numbers which enable individuals to read the text with greater ease. Schriver (1997) argues that the higher the legibility of text, the more effortless the person can read it. Improved legibility relates to giving attention to “contrast, type size, spacing, typeface, leading, justification, line length/width, blank space, graphs and tables, illustrations, and response formats” (Thompson, Thurlow & Malouf, 2004:8).

Maximum legibility was achieved in Plan 2 by focusing on the following aspects:

Dimension	Modifications within the current research study
Contrast	The use of black type on a white background which is pleasing to the eye and legible.
Type size	The font size was increased to 14 points which are conducive to younger learners.
Spacing	A fixed space was used not only between letters but also words which further increases legibility.
Leading	The amount of leading is in line with the type size. Since 14 points were used for the type size, leading between three and six was used.
Typeface	The standard typeface i.e. sentence case was used with the minimum use of italics. Sentence case increases legibility as in the event of all caps or small caps.
Justification	The text wasn't justified since it was found that these type of text are easier to read than justified text.
Line length	The line length was reduced to eight to ten words per line. Increasing the line length to more than ten words increases fatigue amongst readers and they can quickly lose their reading point when they are presented with lengthy sentences.
Blank space	Blank space was used to capture learners' attention which further increases legibility.
Graphs and table	Information on graphs and tables was positioned in the same place so that students could easily find it.
Illustrations	Illustrations were placed directly underneath the question and only had information that was being assessed. Accordingly, the illustrations did not distract learners' attention away from what is being assessed.

Response formats	The response options were increased in size to provide students with enough space to give their answer.
------------------	---

Table 6.6: The maximum legibility achieved in this research project [Adapted: Thompson, Thurlow & Malouf, 2004:9]

In conjunction with the above frameworks, the following modifications were made to address issues raised within Category 3: Potential pitfalls.

The following adjustments were made to ensure the trustworthiness of the research results as well as the validity of inferences being drawn from the results of the OMA. In other words, the following ethical considerations were incorporated within the research study with the aim of ensuring that the credibility of this research study was maintained.

6.9 Protocols to maintain the ethics

To ensure that valid inferences can be drawn from the results of the OMA and that the outcome of the research study is trustworthy, it has to comply with certain ethical considerations. These considerations include fairness, validity, reliability, discrimination and meaningfulness in contributing to learning. Since each of these considerations were already described in Chapter 2, it will now be demonstrated how it was maintained during the current research project.

6.9.1 Fairness

Since the OMA was written specifically for Deaf and H/H learners, the teacher researcher had to make sure that language and written text doesn't become an obstacle for students. Accordingly, difficult words were linked to a Glossary module with signs and explanations. Also, excessive use of imagery, videos, and interactive content was used although only from Plan 2 and Plan 3. In other words, every learner in the Grade 8 class had a fair chance to gain access to the OMA and in no sense were they denied access due to their disability.

6.9.2 Validity

Validity was established within the current research project by ensuring that the assessment instrument measures what it was developed to measure. For instance: the OMA consisted of activities based on the function concept. Therefore, the assessment instrument, in this case, OMA, measured learners' knowledge and skills based on the function concept, nothing more and nothing less. In this case, valid inferences could be drawn from the assessment results and are, therefore, useful for the learning process.

The researcher also made sure that the OMA covers the content based on the function concept. Accordingly, the OMA is based on the function concept as set out by CAPS (DoE, 2011). The assessment, therefore, measures what CAPS (DoE, 2011) expects the learners to achieve at that level.

6.9.3 Reliability

The teacher researcher made sure that direct questions were asked and that the questions didn't mislead the learners in any sense. The rationale behind this was to ensure that the results of the OMA are reliable. Furthermore, the OMA questions were an accurate representation of the content of the function concept set out by CAPS (DoE, 2011). It can thus be said that the OMA are reliable in the sense that when other teachers administer the assessment, it will produce the same results as in the case of the current research project.

Also, the teacher researcher made sure that any obstacle that could influence learners' performance indirectly, was removed. In other words, since this OMA is specific for Deaf and H/H learners who have difficulties with written text, every possible obstacle that written text presents, were eliminated and therefore had no direct influence on students' results.

6.9.4 Discrimination

This feature of the OMA was dealt with in the following manner. Since some learners performed better than others in the OMA, the teacher in conjunction with the students adjusted

the OMA to address certain shortcomings and hence align the assessment to accommodate each student's individual needs.

6.9.5 Meaningfulness in contributing to learning

To ensure the meaningfulness of the OMA the teacher made sure that the assessment items were aligned to what CAPS (DoE, 2011) expects learners to master at the Grade 8 level. Moreover, students were made aware of what exactly they will be tested on and how it is linked to the content specifics i.e. the function concept. Further security measures were based on Marais, Argles and von Solms' (2006) framework to ensure a fair, valid and trustworthy OMA. These measures were administered in the following manner.

Firstly, each Grade 8 learner gained access to the OMA using a secure username and password. They couldn't access the assessment without any other means of authentication. Secondly, the OMA was administered within a safe and controlled environment. In other words, they couldn't access the assessment from home but in the computer room where they were monitored through the whole research process. Thirdly, test items were randomly selected from a question bank, and no two learners answered the same question simultaneously. This measure was set in place to ensure that no cheating is allowed. Finally, students weren't authorized to log in twice and therefore the integrity of the OMA results was never compromised. Moreover, the tracking of each learners' movement via the LMS was recorded and could be accessed after the administration of the assessment to see whether students deviated from the specific assessment. Another measurement that was put in place was the secure storing of students' results of the assessment. No learner had access to his or her results as well as the authority within the LMS to alter any results of the evaluation.

A further measure that was put in place was the Safe Exam Browser and the Safe Exam Browser quiz access rule. The Safe Exam Browser was installed on each user's computer, and they could access the quiz within the browser. Additionally, the Safe Exam Browser quiz access rule creates boundaries within Moodle which prevent users from accessing any other content within Moodle. This also meant that users could not do anything other than the quiz, and as soon as they finished the quiz, it automatically closes.

The following modifications were made to obstacles presented by the screen layout identified in Plan 1.

6.10 Modifications made to the OMA

The next section covers additional changes made to the OMA utilizing suggestions from the users.

6.10.1 Screen layout modifications

A decision was made to place one item on a page to address the issue of too many questions on one page. As a result, learners' attention was focussed on one question alone. Moreover, a plugin was installed to provide students with an option to zoom in on the problem and therefore eliminating any other information. Figures 6.11 and 6.12 illustrate this option.

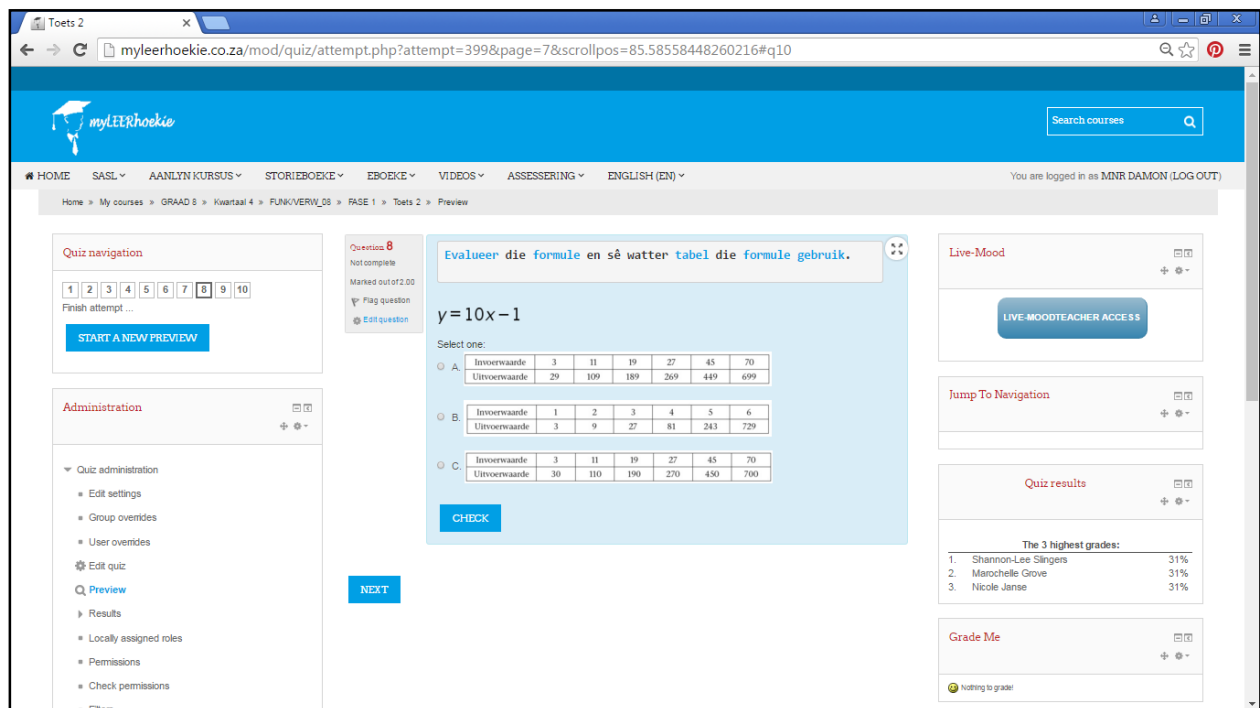


Figure 6.11: An illustration of unnecessary information within the question

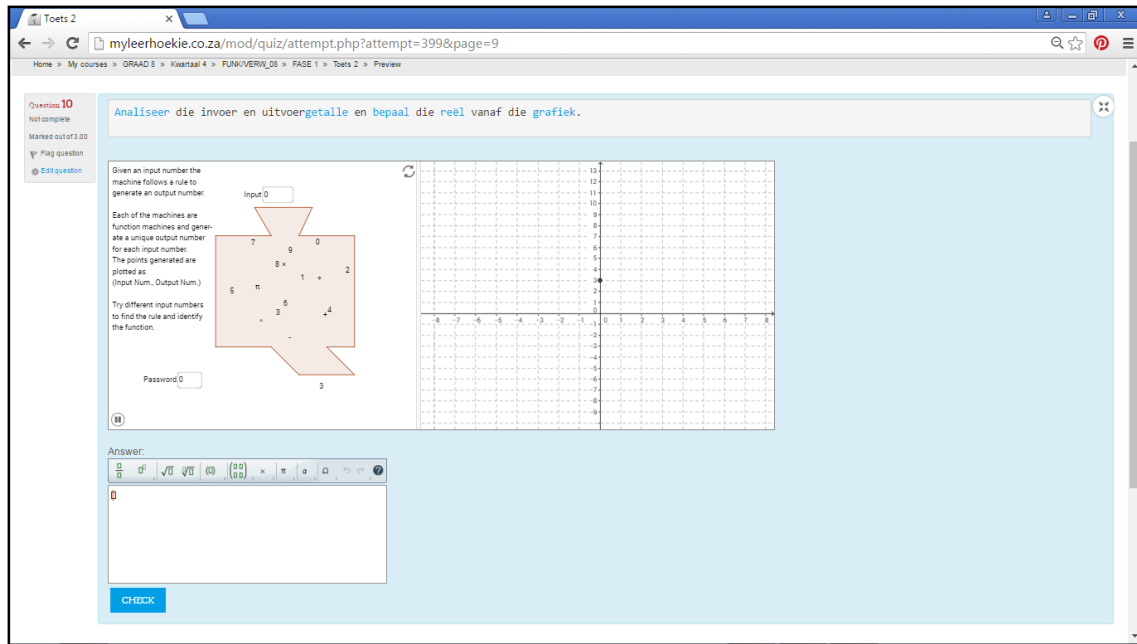


Figure 6.12: An example of the zoom in plugin where only the question is visible

Figures 6.11 and 6.12 illustrate the modifications i.e. one question per page and the option of eliminating unnecessary content from the question, especially those that learners complain about distracting their attention, that was set in place.

The following modifications were made to the obstacles WIRIS presented as identified in Plan 1.

6.10.2 Solving WIRIS problems

Solving the problem of WIRIS i.e. WIRIS not loading, the teacher researcher upgraded all the web browsers of every computer. Also, the JAVA version of each computer was updated, and Internet Explorer was used as the default web browser since it presented the best results when WIRIS was activated.

Solving the problem that learners didn't understand using WIRIS, the teacher researcher allowed students to view video tutorials on the use of WIRIS. The video tutorials were interactive which means that the video stopped playing and provided space for students to interact with it before continuing. This provided students with practice examples to become familiar with using WIRIS.

Figure 6.13 illustrates the use of interactive video to give students opportunities to become familiar with WIRIS.



Figure 6.13: An illustration of the interactive video tutorial integrated into the OMA

Figure 6.13 depicts the interactive video tutorial feature utilized within the OMA. This feature entails a video tutorial on the use and functionality of WIRIS. The video stops at a certain point on the timeline and presents learners with a multiple choice quiz to test their skills on elements within WIRIS. The interactive video was very helpful in that it assists students in their understanding of how to use WIRIS.

The following adjustments were made to improve accessibility to the OMA.

6.10.3 Increased accessibility

From the data extracted through the different data collection techniques, it became apparent that problems with the internet were there to stay. A workaround this issue was to install Moodle on our local server. This meant that Moodle was running from the central computer (server) in the mathematics lab and was not dependent on internet access. Moreover, the loading speed of the

OMA increased and whether the Internet is up or down, it didn't influence accessing and interacting with the OMA.

A solution to assist learners with difficulties in remembering the web address was to make the OMA website the home page of the internet browser. Essentially, this means that when any user clicks on the web browser, the OMA login page will appear. All the users appreciated this solution and had instant access to the OMA website. However, this quick fix presented other problems. Firstly, not knowing or remembering the web address of the OMA means that users couldn't access the website from any other place than the mathematics lab. Secondly, they will not be able to advise other users on how to access the website. This problem was addressed by allowing users to memorize the site's name i.e. '*myleerhoekie*' and typing it in any web browser which in turn will present them with a link they could click on to locate the OMA website.

6.11 Action (implement plan 2)

Learners were provided opportunities to engage in the adjusted OMA, and again they had to keep a journal. The teacher observed their interactions by making use of an observation schedule.

6.12 Observation (what worked/ did not work)

Figure 6.14 below is an illustration of the marks users obtained in the OMA based on the function concept.

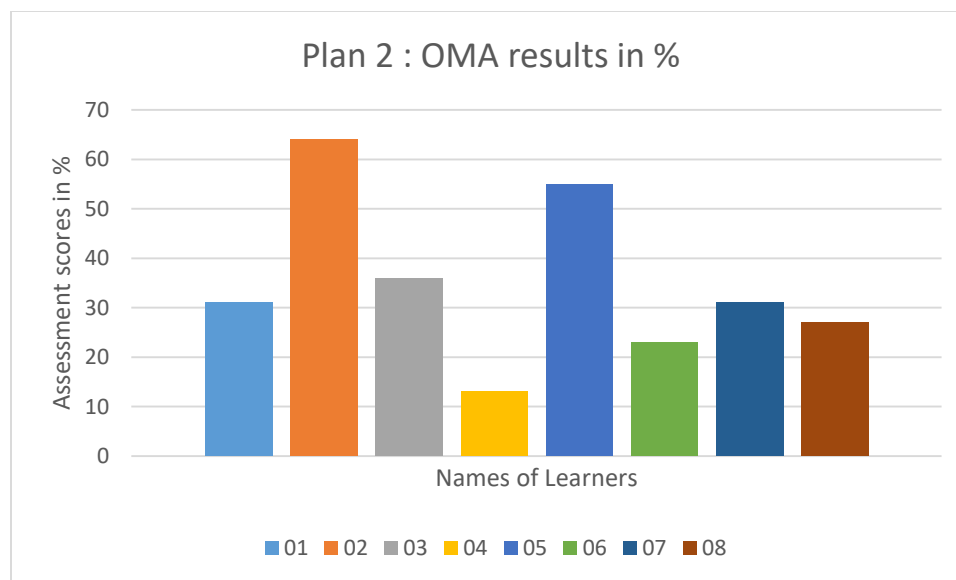
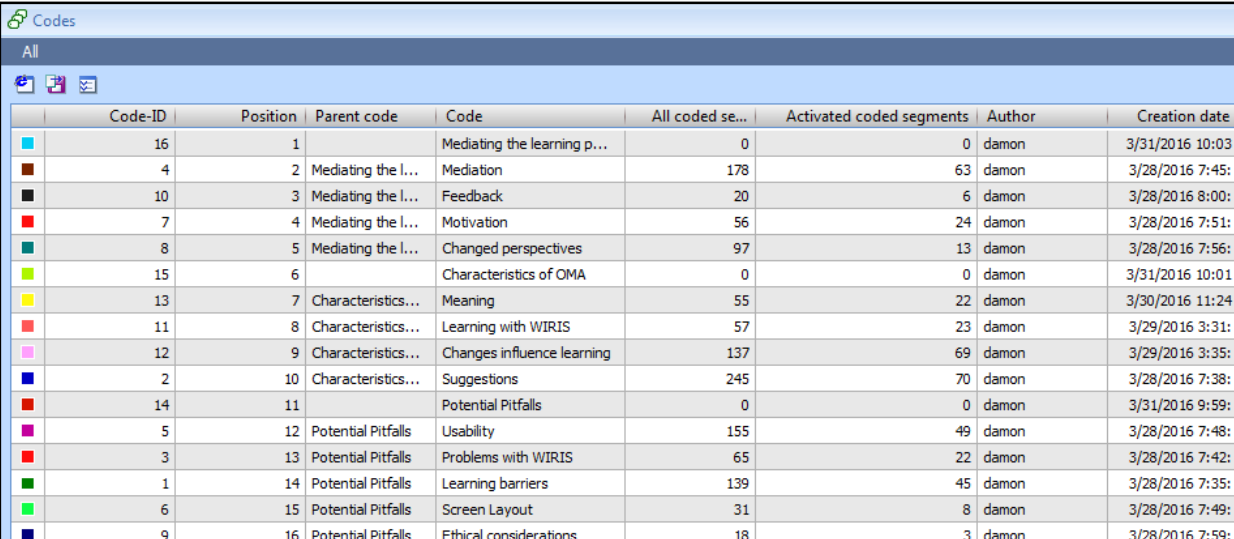


Figure 6.14: Plan 2 of the OMA results

As seen from Figure 6.14 there were improvements in the OMA scores after adjustments were made. In contrast to the six learners who failed, two students passed the OMA. Moreover, from the two students who passed one obtained a score more 60% in the OMA. Also, three students achieved a mark higher than 30%, and only one student scored lower than 20%. In other words, based on the adjustments made to the OMA, there was an improvement in the assessment scores.

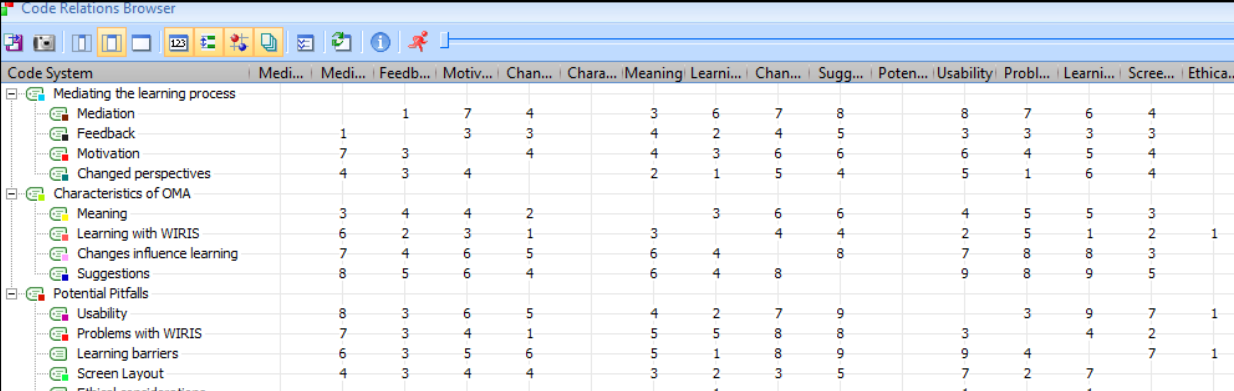
After administering Plan 2 of the OMA based on the function concept, learners were asked to take part in an interview as part of the reflection cycle. The data extracted from the journal entries of the students, together with the field notes the teachers-researcher captured in the form of an observation schedule, as well as the interview the teacher-researcher conducted with the learners, were transcribed and uploaded to MAXQDA. The text was coded and further analyzed in search of concepts and themes. Figures 6.5 and 6.6 are illustrations of the categories and subcategories that were identified within Plan 2. A detailed description follows.



	Code-ID	Position	Parent code	Code	All coded se...	Activated coded segments	Author	Creation date
	16	1		Mediating the learning p...	0	0	damon	3/31/2016 10:03
	4	2	Mediating the l...	Mediation	178	63	damon	3/28/2016 7:45:
	10	3	Mediating the l...	Feedback	20	6	damon	3/28/2016 8:00:
	7	4	Mediating the l...	Motivation	56	24	damon	3/28/2016 7:51:
	8	5	Mediating the l...	Changed perspectives	97	13	damon	3/28/2016 7:56:
	15	6		Characteristics of OMA	0	0	damon	3/31/2016 10:01
	13	7	Characteristics...	Meaning	55	22	damon	3/30/2016 11:24
	11	8	Characteristics...	Learning with WIRIS	57	23	damon	3/29/2016 3:31:
	12	9	Characteristics...	Changes influence learning	137	69	damon	3/29/2016 3:35:
	2	10	Characteristics...	Suggestions	245	70	damon	3/28/2016 7:38:
	14	11		Potential Pitfalls	0	0	damon	3/31/2016 9:59:
	5	12	Potential Pitfalls	Usability	155	49	damon	3/28/2016 7:48:
	3	13	Potential Pitfalls	Problems with WIRIS	65	22	damon	3/28/2016 7:42:
	1	14	Potential Pitfalls	Learning barriers	139	45	damon	3/28/2016 7:35:
	6	15	Potential Pitfalls	Screen Layout	31	8	damon	3/28/2016 7:49:
	9	16	Potential Pitfalls	Ethical considerations	18	3	damon	3/28/2016 7:59:

Figure 6.15: TU of plan two as coded in MAXQDA

Figure 6.15 is an illustration of the categories and subcategories that surfaced through the coding procedures. It also provides a clear picture of color codes of each category and subcategory as well as the activated code segments.



Code System	Medi...	Medi...	Feedb...	Motiv...	Chan...	Chara...	Meaning	Learni...	Chan...	Sugg...	Poten...	Usability	Probl...	Learni...	Scree...	Ethica...
Mediating the learning process																
Mediation			1	7	4		3	6	7	8		8	7	6	4	
Feedback				3	3		4	2	4	5		3	3	3	3	
Motivation			7	3	4		4	3	6	6		6	4	5	4	
Changed perspectives			4	3	4		2	1	5	4		5	1	6	4	
Characteristics of OMA																
Meaning			3	4	4	2		3	6	6		4	5	5	3	
Learning with WIRIS			6	2	3	1		3		4		2	5	1	2	1
Changes influence learning			7	4	6	5		6	4	8		7	8	8	3	
Suggestions			8	5	6	4		6	4	8		9	8	9	5	
Potential Pitfalls																
Usability			8	3	6	5		4	2	7	9		3	9	7	1
Problems with WIRIS			7	3	4	1		5	5	8	8			4	2	
Learning barriers			6	3	5	6		5	1	8	9		9	4	7	1
Screen Layout			4	3	4	4		3	2	3	5		7	2	7	
Ethical considerations									1				1		1	

Figure 6.16: Code relation browser within MAXQDA

Figure 6.16 provides a screenshot of all the coded segments as well as how each section links to other segments within the different categories and subcategories.

The table below provides a detailed description of the categories and subcategories that emerged during Plan 2. A detailed analysis follows.

CATEGORY	SUB CATEGORY	TU TOTAL	TU %
Characteristics of OMA	Simplicity	22	11.96
	Learning with WIRIS	23	12.5
	Changes that influenced learning	69	37.5
	Suggestions	70	38.04
	TOTAL	184	100
Mediating the learning process	Feedback	6	5.66
	Motivation	24	22.64
	Changing perspectives	13	12.26
	Mediation	63	59.44
	TOTAL	106	100
Potential pitfalls	Ethical consideration	3	2.36
	Screen layout	8	6.31
	Problems with WIRIS	22	17.32
	Learning barriers	45	35.43
	Usability	49	38.58
	TOTAL	127	100
TOTAL TUs CODED		417	100

Table 6.7: The categories and subcategories identified within MAXQDA for Plan 2

6.13 Findings based on the interviews, journal entries and field notes based on Plan 2

Table 6.7 illustrates that a total of 417 TU were coded which included 184 TU related to the Characteristics of OMA, 106 TU related to Mediating the learning process and 127 TU related to Potential pitfalls. An astonishing discovery from the learners' answers was that the potential pitfalls decreased from 237 TU in plan 1 to 127 TU in plan 2. Accordingly, one can assume that the Deaf and H/H learners experienced fewer obstacles than in plan 1. Also, the subcategories, 'learning with WIRIS' (from 2.5% to 12.5%) and 'changes that influenced learning' (from 7.5% to 37.5%) increased. It can thus be noted that Deaf and H/H learners experience with WIRIS improved, and the modifications to the OMA had a positive effect on the learning process of these students.

The category '*Mediating the learning process*' also illustrated changes. It decreased from 149 TU to 106 TU. However, the latter TU are based on positive feedback from the learners about how the OMA provided them with assistance. For instance, during Plan 1, the users had a negative perception about the OMA, and it influenced their learning. During Plan 2 their attitudes changed and they raised views such as user NH" *nou maklik, elke vraag help met voorbeeld*"; user MS" *baie verander nou beter kinders verstaan nou in klas almal beter sê beter as eerste baie beter, wys my hoe ek moet maak, verstaan beter hoe ek moet maak*". However, there were still users that required more assistance, and this became visible in the answers they presented during the interview sessions. For example, user NH asserts that more help is needed i.e. "*verander nou nog dan wys dit my en help.*" User MG agreed with this view and answered "*nogie verstaan heeltemal nie.*" Also, user RB is of the opinion that more assistance might improve their understanding ('*nog meer help nodig vir my en ander kinders*').

Additionally, the '*learning barriers*' also decreased (from 86 TU to 45 TU) as well as a decline in '*usability*' issues (from 78 TU to 49 TU). Both these reductions might be due to the modification made to the original OMA.

6.14 Reflection (interpret and analyze findings)

Again learners were asked to take part in an interview session. Together with the interview results, the data from the journal entries, data from the observation done by the teacher-researcher as well as the log files from Moodle, the following obstacles were detected.

- Participants complain they need more help in answering the questions;
- they need some help when their answers are wrong;
- they require more help in interpreting the questions;
- they need to be more engaged in the OMA;
- they struggle to access definitions of words in Sign Language;

After discussions between learners and the teacher-researcher, it was agreed that further adjustments had to be made to the OMA.

6.15 Plan 3

Modifications to the OMA were done based on users' suggestions, the teacher researcher's observation, and a detailed literature review.

6.15.1 High quality online assessment

It was decided to use Parshall and Harmes' (2007) framework for high quality online assessments. It consists of seven dimensions such as assessment structure, complexity, fidelity, interactivity, media inclusion, response action, and scoring model. Each of these dimensions will be used to modify the current OMA based on the function concept.

6.15.1.1 Assessment structure

The assessment structure, also known as item format, highlights the way in which the different parts of the assessment are arranged (Parshall and Harmes', 2007). These researchers also argue

that Computer Based Tests (CBT) have prospects of advancing above discrete items, via situated tasks and simulated environments. CBT is an umbrella term which encapsulates online assessments or computer based quizzes.

Firstly, CBTs consists mainly of discrete items which are categorized in either selected or constructed response items (CR). A selected response item is an item type where learners have to make a selection based on the question. These selected item responses can consist of questions such as multiple choice items, hot spot items, matching items, multiple response items, ordered response items, etc. On the other hand, the constructed response questions provide learners with the space to create their answers. These can include numerical response items, short items, embedded items, interaction items, etc. The more sophisticated the constructed-response items, the more it moves towards a situated task or a simulated environment (Parshall and Harnes', 2007).

Both the item response categories add quality to CBT because of its measurement attributes. Also, it has the potential to reduce the chances of guessing in an assessment. For example, a selected response question can ask learners to move a formula to a point on a graph. Not only does this type of question add value to the quality of measurement but it also reduces guessing since only one part of the image is focussed on.

Secondly, situated tasks involve the use of ICTs to stage a scenario or an interactive simulation. In other words, learners can be asked to interact with a simulation and based on their interaction follow a few steps to complete the response. For example, presenting learners with a simulation of a function machine with empty input and output boxes as well as a rule to apply to the input or output values and asking students to plot the values on either a graph or a table. Students are scored on the correct items, and answers are incorrect if they fail to provide a reply or provide a wrong answer.

Finally, simulated environments entail replicating a scenario in real world settings. This is done by presenting learners with problems in real-world situations in which the learners have to use real tools to solve the problem or answer the questions. Examples of simulated environments can be found in the aviation industry where flight simulators are used to train and assess pilots. Since this was not the aim of the current research project, it will not be discussed further.

The assessment structure of the current research project includes discrete items as well as situated tasks. Firstly, the discrete items consisted of selected and constructed response items. The selected response items were done using different question types. The question types that was utilized as a selected response includes multiple choice items, hot spot items, matching items, multiple response items, true or false items.

Additionally, constructed response items were used within the current research project. CR items denote learners providing their answers while utilizing an input device like a keyboard or a mouse. The CR items included within this research project include numerical response items, short items, embedded items, interaction items. A point that needs to be noted is that for both the selected and constructed response items, the WIRIS CAS was used. In other words, WIRIS as a CAS and an editor were used to create the different assessment items and were utilized by the learners to respond to the questions.

The structure of the assessment items also included situated tasks. Situated tasks denote students engaging in interactive simulations that represent a particular subject matter object. Within the current research project, GeoGebra simulations were used. Essentially, this means that content based on the function concept was constructed using GeoGebra. “GeoGebra is dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package” (GeoGebra, 2015:1). Figure 6.17 provides an illustration of an interactive simulation that was constructed using GeoGebra.

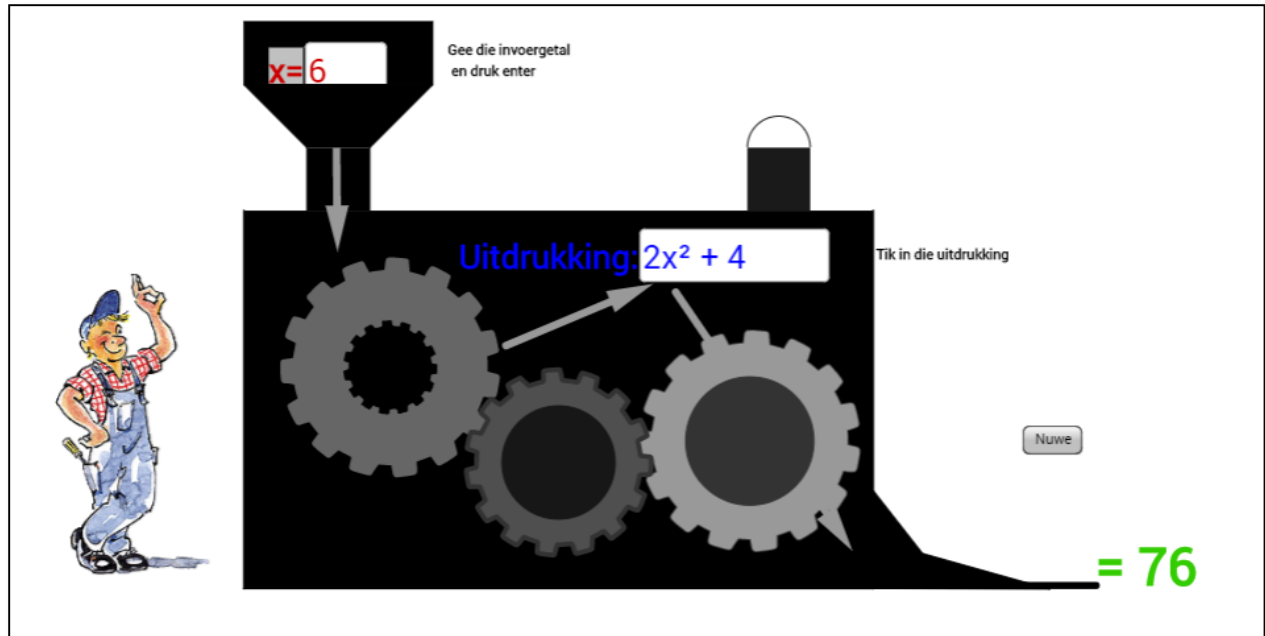


Figure 6.17: Situated task created in GeoGebra

The above-situated task consists of an interactive simulation. Learners have to provide the x -value, press enter, and the machine generates an answer. Additionally, learners can also insert an expression and construct a table and a graph from the obtained x and y values.

6.15.1.2 Complexity

Complexity highlights the quality of intricacy of the items within an assessment and everything the learner needs to perceive to answer the question (Parshall and Harnes', 2007). For example, items in an assessment might include images, video, and audio, interactive content as well as its onscreen placement which the learner must be aware of before answering the question.

Therefore, a more complex item considers more interpretation from the part of the student whereas a less complicated question is more straightforward in explaining. One can thus argue that an enhanced complexity is underpinned by an increase in visual elements on the screen and "in many cases increased complexity is likely to be associated with an increase in the item's cognitive challenge" (Parshall and Harnes, 2007:7).

Each item within the OMA consisted of text, video, interactive content, and simulations. Primarily, high levels of complexity were maintained within each question. Not all of these

items were placed on the screen at once. Some of the items were hidden, and learners had to activate it by either clicking on a link or a button. Moreover, since written text is a major obstacle for Deaf and H/H learners, certain text units were connected to Glossary items which provided them with either a definition or a translation of the word into Sign Language. Figure 6.18 illustrates the high level of complexity that was maintained within the OMA items.

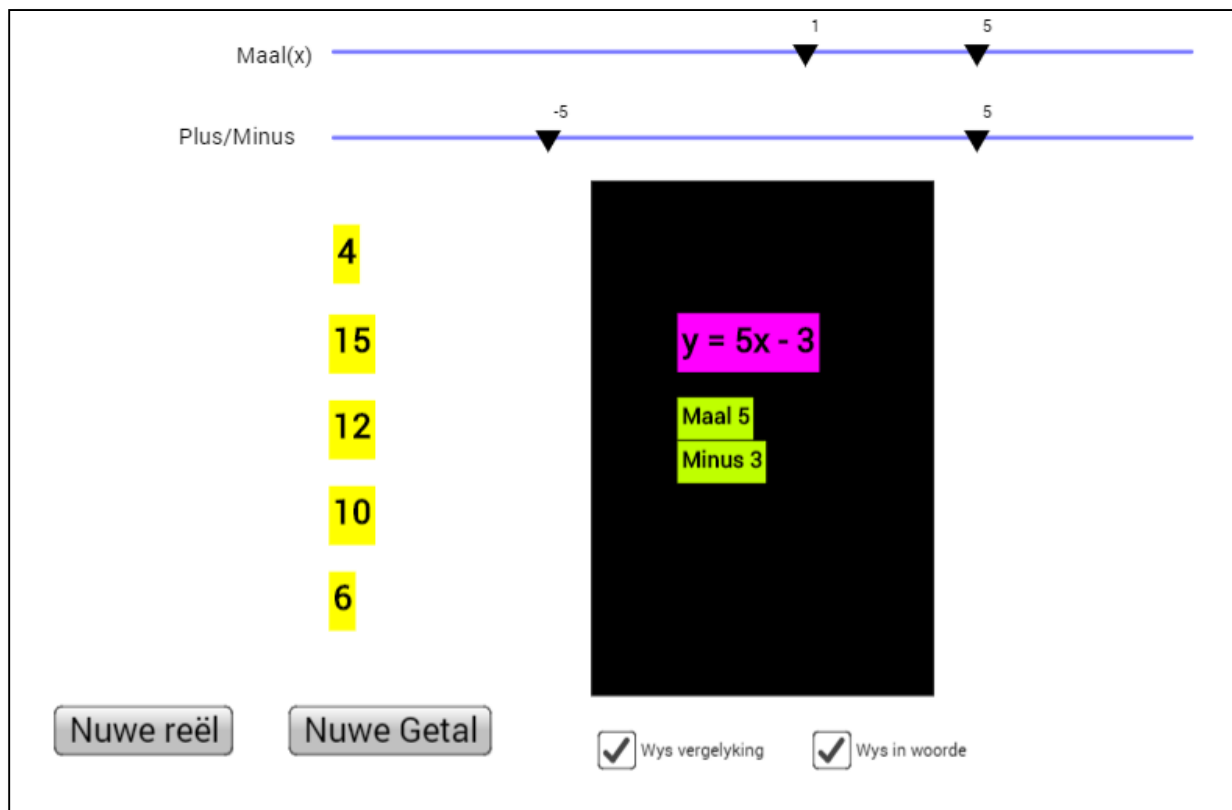


Figure 6.18: High-level complexity of elements in the OMA

The simulation involves learners interacting with the function machine and manipulating the different factors that influence the x and y values. From this, they can either complete a table or create a graph based on the x and y values.

6.15.1.3 Fidelity

According to Parshall & Harmes (2007), fidelity is the way in which the item within the assessment is a replica of the actual object being assessed. Therefore, the more accurate the

model represents the actual object or situation, the higher the fidelity level. For example, using mathematics simulations within an assessment should be an authentic reproduction of the real mathematical object being assessed. In this case, a high level of fidelity is achieved.

Fidelity within the current research project was maintained through the use of interactive simulations as well as representations of real mathematics objects. Figure 6.19 illustrates how fidelity was administered.

Analiseer die tabel en gee die formule wat gebruik is.

Getal rooi kolletjies	1	2	3	4	5	6
Getal blou kolletjies	6	10	14	18	22	26

Onthou: Getal rooi kolletjies (x)
 Getal blou kolletjies (y)

Answer:

$\frac{\Box}{\Box}$
 \Box^\Box
 $\sqrt{\Box}$
 $\sqrt[\Box]{\Box}$
 (\Box)
 (\Box^\Box)
 \times
 π
 a
 Ω
 \leftarrow
 \rightarrow
?

CHECK

Figure 6.19: An illustration of a realistic view of input and output values from a function machine

6.15.1.4 Interactivity

Interactivity refers to the manner in which the item changes based on the learners' item input. For example, presenting students with a simulated mathematics problem, based on their contribution, the problems outcome changes. Accordingly, they can immediately see the effects of their individual interactions and make choices based on the results of their interactions. In other words, nothing happens without learners interacting with the item. Parshall and Harmes (2007) argue that increased interactivity highlights an exact replication of the actual object under study which in turn provides teachers with greater insights into the thought processes of learners.

Interactivity was sustained in the current research project through the use of GeoGebra interactive mathematics content. The students could engage with the mathematics objects as if it were real. Their input or outputs on the function machine changed not only the graph but also the formula of the graph. Learners could thus experience a representation of three formats of the function concept i.e. function machine, graph, and formula. Figure 6.20 is an illustration of how interactivity was maintained.

Analiseer die invoer en uitvoergetalle en bepaal die reël vanaf die grafiek.

Given an input number the machine follows a rule to generate an output number.

Each of the machines are function machines and generate a unique output number for each input number. The points generated are plotted as (Input Num., Output Num.)

Try different input numbers to find the rule and identify the function.

Input:

Output:

Machine diagram showing a flow from input to output with various mathematical operations: \times , $+$, $-$, \div , π , $\sqrt{\quad}$, $\sqrt[3]{\quad}$, $\frac{\square}{\square}$.

Password:

Graph area with x-axis from -8 to 8 and y-axis from -9 to 13.

Answer:

Figure 6.20: Interactive mathematics content which changes through responses by learners

6.15.1.5 Media inclusion

Media inclusion refers to the incorporation of media elements within assessment items.

Examples of media items include video, audio, graphics, animations, interactive content, etc. Not only does the inclusion of media elements within an assessment increase learners' understanding of the content being assessed but it also increases the validity of the assessment (Parshall and Harmes, 2007).

Different types of media were incorporated within the OMA. These include video, interactive content, graphics, text, and animation. Video elements were mainly used to provide learners with help while answering each question. The help videos were in the form of worked out examples

which students could interact with. Each question had some graphical illustration which provided students with accurate representations of the mathematics objects i.e. table, function machine, graph, etc. The interactive content was designed with the purpose of presenting students with space to play with realistic mathematical objects and to provide learners opportunities to make possible mathematical deduction by asking specific questions.

6.15.1.6 Response action

Response action refers not only to the input device used to deliver a response to the question but also the measures taken by the learner to answer the question. The most commonly used input devices are computer keyboards and a mouse. Students use keyboards to input text, numbers, and other characters if required of them. Also, they use the mouse to select answers, drag items across the screen or make an insertion point for keyboard input. More advanced testing uses touchpads, a touchscreen, a stylus, a graphics tablet, etc. A point that needs to be taken into consideration is that the input device should fit the purpose required by the assessment. In other words, the input device should not become an obstacle while taking the assessment and therefore jeopardize the inferences being drawn from the results of the evaluation.

The response action that was utilized within the current research project was mainly the keyboard and the mouse. Learners used the standard QWERTY keyboard to provide constructed response items and the mouse to provide selected response items. Since students were familiar with both the keyboard and the mouse, it didn't hinder them from providing a response to the assessment items.


6.15.1.7 Scoring model

Scoring entails, the allocation of marks after the assessment is administered. As with CBT, scoring is usually done immediately, and therefore test results are readily available. However, there are models available where CBT are scored through the use of criteria developed in advance as well as giving partial credit for partially correct answers. The use of a scoring model rests on the test developer and the kind of test he/she needs to develop.








Three models are currently available for CBT i.e. dichotomous, polytomous and sophisticated modeling. In the case of dichotomous, scoring is done automatically by scoring items either correct or incorrect. Polytomous involves giving partial credit for partially correct responses. In other words, responses are weighted and based on its weighting; a score is given. Similarly, this type of scoring involves setting the number of criteria as well as determining the weighting of each criterion.

Since Moodle was used to administer the OMA, the scoring model that was used included both polytomous and dichotomous. In other words, for some answers correct and incorrect scoring were done and for others partial credit was given for partially correct answers. The polytomous model was mostly used for selected response items while the dichotomous model was used for constructed response items.

Since the OMA was done in different modes of testing i.e. adaptive, immediate feedback, interactive with multiple responses, correct answers were captured while constructing the assessment items. In other words, the test administrator must provide the proper answer to the different questions and the response of the learners are measured against the right answer. If the students' answer is correct, the maximum amount of marks is given, however failing to provide the right answer results in receiving no marks for that specific question. Figure 6.21 and 6.22 presents an illustration of the scoring model for both polytomous and dichotomous models. In the case of the dichotomous scoring model, the CAS verifies the answer whether the syntax is correct and whether the answer is mathematically equal to the right answer. Therefore, partial credit is given for the right answer.

Answer 1 $y = 4x + 2$  Grade 100% ▾

Feedback


Paragraph ▾ B I       

Wat is die verskil tussen die y-waardes.








Gebruik nou die verskil om by die ander y-waardes te kom.


Kyk na die video om jou te help.

Path: p


Answer 2 $y = 4x - 2$  Grade None ▾

Feedback








Paragraph ▾ B I       


 Nee, jammer. Kyk na die video en maakseker dat jy verstaan.

Path: p

Answer 3 $y = 2x + 4$  Grade None ▾

Feedback

Paragraph ▾ B I       

 Nee, jammer. Kyk na die video en maak seker dat jy verstaan.

Path: p

BLANK FOR ANOTHER CHOICE

▼ Multiple tries


Penalty for each incorrect try  33.33333% ▾

Figure 6.21: The polytomous scoring model used in the OMA

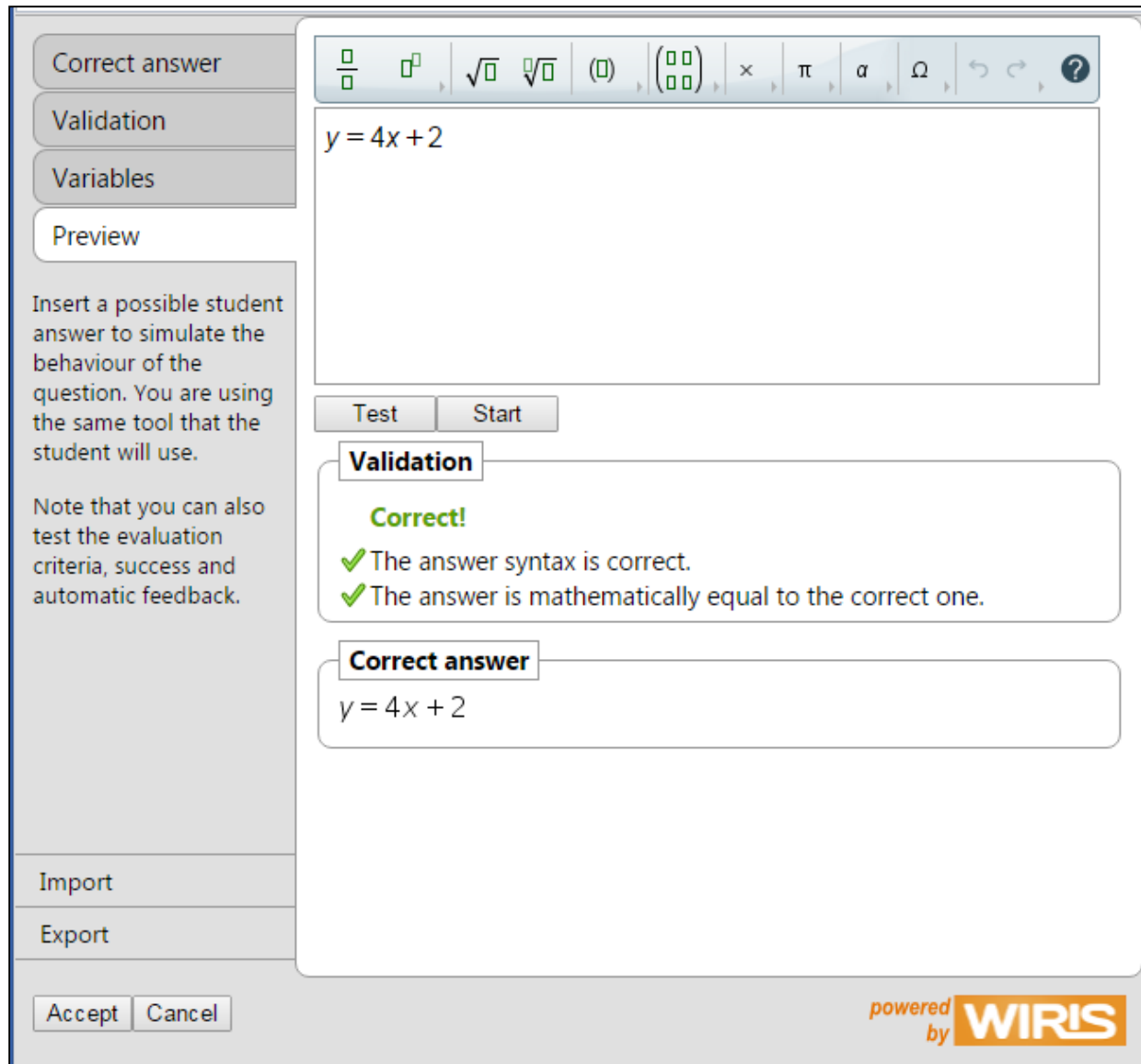


Figure 6.22: The dichotomous scoring model used in the OMA

As seen from the above discussion the OMA items comply with all seven of Parshall and Harmes' (2007) framework for high quality online assessments. The most prominent feature was the media component, and since the OMA was created specifically for Deaf and H/H learners who are dependent on visual imagery for learning, it has the potential to assist them with the teaching and learning.

A further shortcoming of the OMA based on the function concept was that the teacher researcher struggled to gain insight into the cognitive functions of Deaf and H/H learners. Although the test scores painted a picture of their understanding, it wasn't an objective one. In other words, the teacher researcher was in need of a tool to measure the thought processes that takes place in Deaf and H/H learners mind when trying to answer questions on the function concept. This will be referred to in the discussion section of this research project.

6.16 Action (implement plan 3)

Learners engaged in the OMA and kept a journal of their experience. Similarly, the teacher kept field notes in the form of an observation schedule and extracted data from the log files.

6.17 Observation

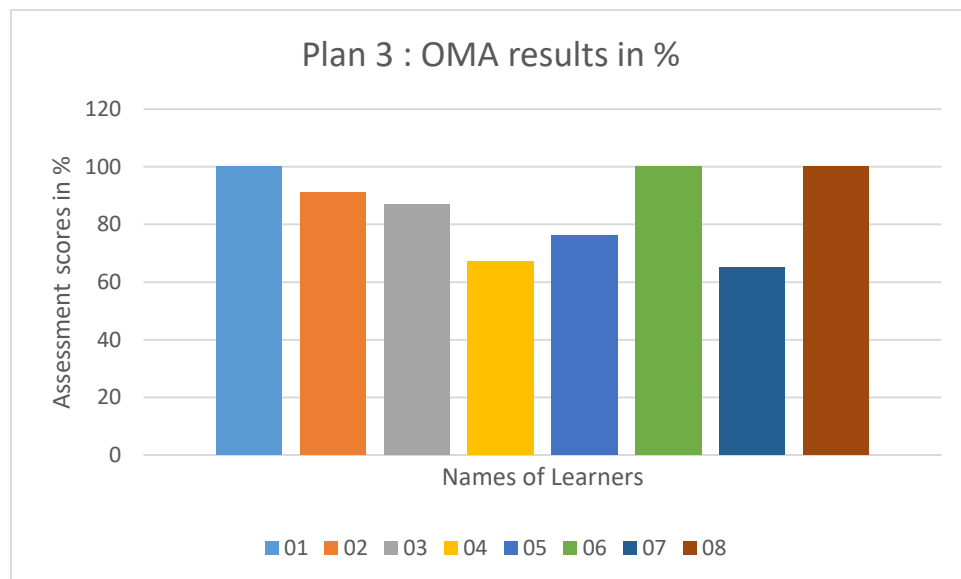
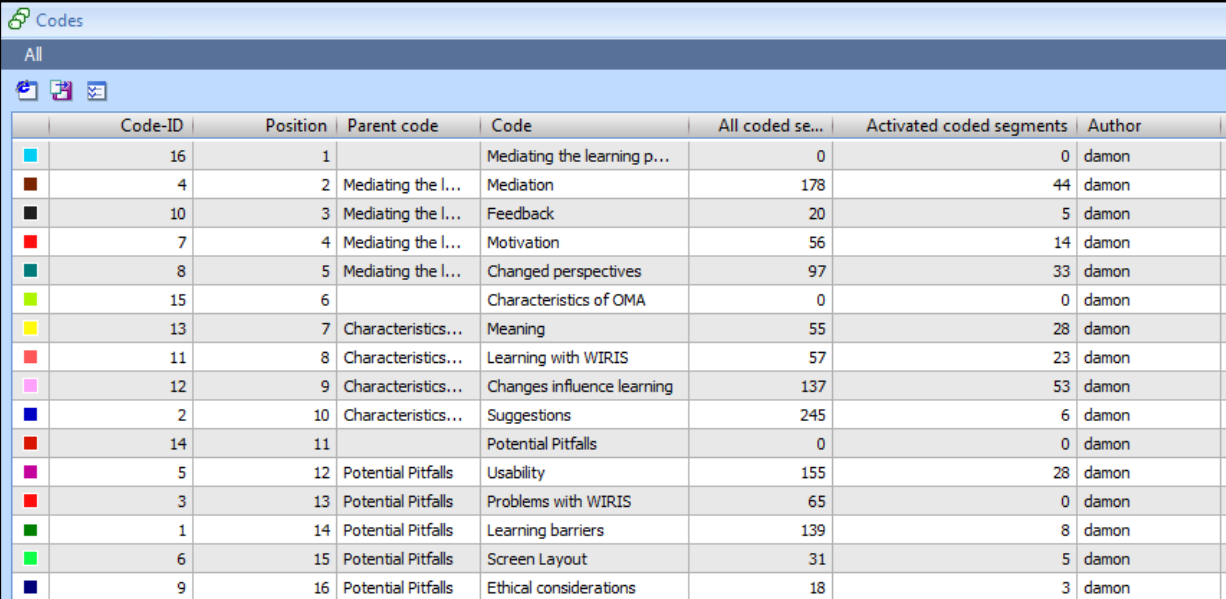


Figure 6.23: Phase 3 of the OMA results

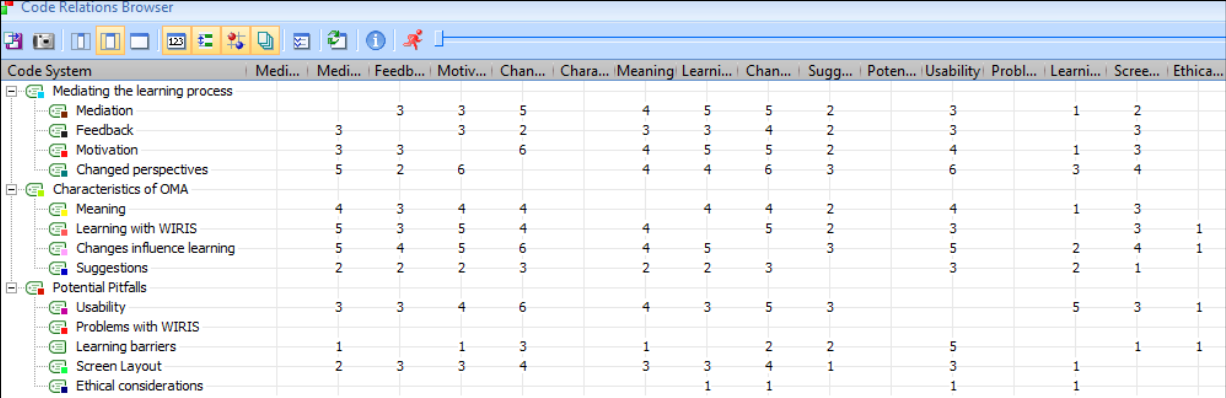
From Figure 6.23 it can be noticed that adjustments made to the OMA in Phase 3 rendered somewhat positive results. As illustrated, three learners obtained 100%, while two students achieved 90%. The whole class passed the test, all above the 50% pass mark.

After administering Plan 3 of the OMA based on the function concept, learners were asked to take part in an interview as part of the reflection element. The data extracted from the journal entries of the students, together with the field notes the teachers captured in the form of an observation schedule, as well as the interview the teacher conducted with the learners, were transcribed and uploaded to MAXQDA. The text was coded and further analyzed in search of concepts and themes. Figures 6.24 and 6.25 are illustrations of the categories and subcategories that were identified within plan 3. A detailed description follows.



	Code-ID	Position	Parent code	Code	All coded se...	Activated coded segments	Author
	16	1		Mediating the learning p...	0	0	damon
	4	2	Mediating the l...	Mediation	178	44	damon
	10	3	Mediating the l...	Feedback	20	5	damon
	7	4	Mediating the l...	Motivation	56	14	damon
	8	5	Mediating the l...	Changed perspectives	97	33	damon
	15	6		Characteristics of OMA	0	0	damon
	13	7	Characteristics...	Meaning	55	28	damon
	11	8	Characteristics...	Learning with WIRIS	57	23	damon
	12	9	Characteristics...	Changes influence learning	137	53	damon
	2	10	Characteristics...	Suggestions	245	6	damon
	14	11		Potential Pitfalls	0	0	damon
	5	12	Potential Pitfalls	Usability	155	28	damon
	3	13	Potential Pitfalls	Problems with WIRIS	65	0	damon
	1	14	Potential Pitfalls	Learning barriers	139	8	damon
	6	15	Potential Pitfalls	Screen Layout	31	5	damon
	9	16	Potential Pitfalls	Ethical considerations	18	3	damon

Figure 6.24: TU of plan three as coded in MAXQDA



Code System	Medi...	Medi...	Feedb...	Motiv...	Chan...	Chara...	Meaning	Learni...	Chan...	Sugg...	Poten...	Usability	Probl...	Learni...	Scree...	Ethica...
Mediating the learning process																
Mediation			3	3	5		4	5	5	2		3		1	2	
Feedback			3	3	2		3	3	4	2		3			3	
Motivation			3	3	6		4	5	5	2		4		1	3	
Changed perspectives			5	2	6		4	4	6	3		6		3	4	
Characteristics of OMA																
Meaning			4	3	4			4	4	2		4		1	3	
Learning with WIRIS			5	3	5		4		5	2		3			3	1
Changes influence learning			5	4	5		4	5		3		5		2	4	1
Suggestions			2	2	2		2	2	3			3		2	1	
Potential Pitfalls																
Usability			3	3	4		4	3	5	3				5	3	1
Problems with WIRIS																
Learning barriers			1		1		1		2	2		5			1	1
Screen Layout			2	3	3		3	3	4	1		3		1		
Ethical considerations								1	1			1		1		

Figure 6.25: Code relation browser within MAXQDA

The table below provides a detailed illustration of the categories and subcategories that surfaced during Plan 3. A detailed analysis follows below.

CATEGORY	SUB CATEGORY	TU TOTAL	TU %
Characteristics of OMA	Simplicity	28	25.45
	Learning with WIRIS	23	20.91
	Changes that influenced learning	53	48.18
	Suggestions	6	5.45
	TOTAL	110	100
Mediating the learning process	Feedback	5	5.21
	Motivation	14	14.58
	Changing perspectives	33	34.38
	Mediation	44	45.83
	TOTAL	96	100
Potential pitfalls	Ethical consideration	3	6.82
	Screen layout	5	11.36
	Problems with WIRIS	0	0
	Learning barriers	8	18.18
	Usability	28	63.64
	TOTAL	44	100
TOTAL TUs CODED		250	100

Table 6.8: The categories and subcategories identified within MAXQDA for Plan 3

6.18 Findings based on the interviews, journal entries and field notes

Table 6.8 illustrates that a total of 250 TU were coded which include 110 TU related to the characteristics of OMA, 96 TU related to mediating the learning process and 44 TU related to potential pitfalls. Further analysis of the answers provided by the participants indicates that the potential pitfalls were reduced to only 44 TU. Also, less ethical issues and problems with WIRIS were observed and reported. Moreover, the learning barriers and usability issues decreased to as little as eight TU and 28 TU irrespectively.

6.19 Reflection (interpret and analyze findings)

During the OMA the learners were asked to keep a journal and make notes as they go along. After the OMA was administered the Grade 8 Deaf and H/H students have been invited to participate in an interview session. The following data were extracted from their journal entries, interviews and observation that was done by the teacher-researcher:

- learners enjoyed the newly constructed OMA;
- they appreciated the help function within each question;
- the feedback after each question was helpful and meaningful;
- the highlighted words that could be clicked to show a popup of definitions of words was useful;
- they liked playing with the interactive content;
- the WIRIS tool made it easy for them to represent mathematical functions and answer questions on the function concept;
- The video examples assist them in guiding their understanding of the function concept;
- They appreciated the overall use of Sign Language as an alternative to text-based questions;
- They found the screen layout and some usability features helpful.

6.20 Conclusion

All in all, the newly adapted OMA was well accepted by all students, and it was visible through their assessment results. Figure 6.26 is an illustration of the combined results of the OMA.

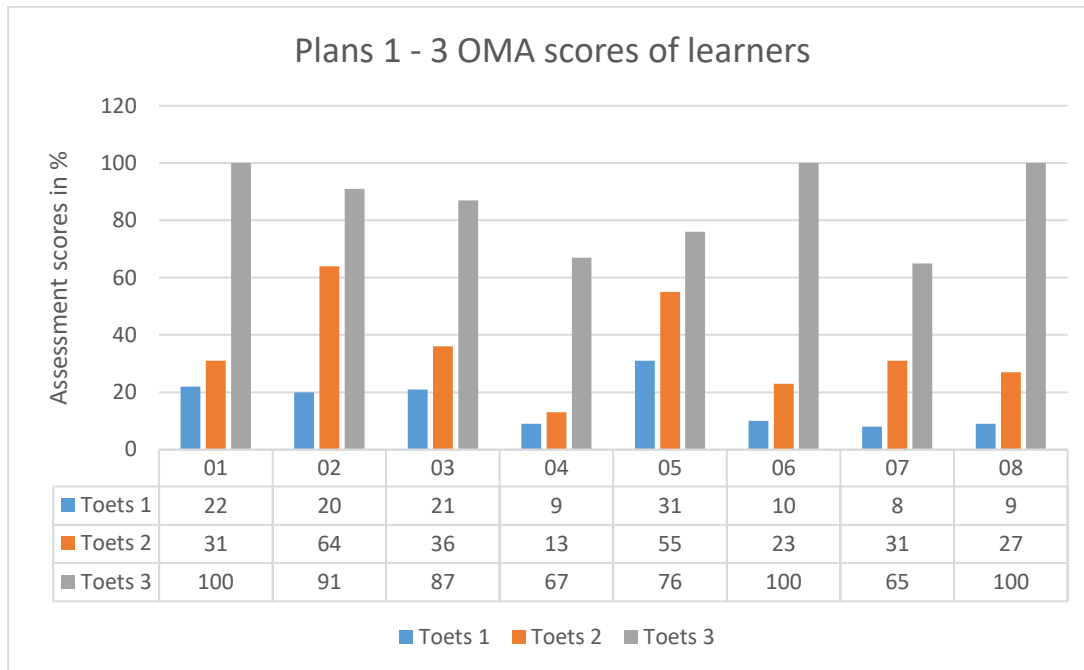


Figure 6.26: Plans 1 – 3 OMA scores of learners

Observing figure 6.26, it becomes apparent that users didn't do so well in Test 1 (Plan 1). All of the users failed the test and scored as low as 8% for the entire test. A slim improvement is visible in Test 2 (Plan 2). Although only two users passed the test, all other users' marks improved in relation to Test 1. A vast improvement can be noticed in Test 3. All of the users passed the test with three learners obtaining a score of 100%. Also, all of the users received marks above 60%. It can thus be accepted that the modifications to the OMA resulted in improvements in the users' test scores. Since an improvement in test scores are directly linked to an increase in users' understanding, it can be argued that due to modifications to the OMA, the users' knowledge based on the function concept improved. However, further analysis had to be done to investigate whether this was, in fact, the case. This will be revisited in the discussion section below.

6.21 Discussion

This section of the research project includes a detailed discussion of the data analysis and findings based on the different data collection techniques. The discussion is structured around answering the three research questions that were identified by this research project. The rationale for presenting it in such a manner is to provide readers with possible answers to these research questions by highlighting discoveries made through an in-depth investigation. The questions will thus be answered in the same manner it is posed in chapter 1.

In answering the first question: *what characteristics should online mathematics assessment adhere to in order to provide mathematics teachers with insights into the cognitive functions and dysfunctions of Deaf and H/H learners*, it was necessary to use the revised Bloom's taxonomy in conjunction with Webb's (1999) Depth of Knowledge (DOK) together with Hess's (2006b) Cognitive Rigor Matrix (CR).

The next section focusses on the revised Bloom's taxonomy (Anderson-Krathwohl, 2001), Webb's DOK model and Hess's (2006b) CR model and why it was employed within the current research project.

6.21.1 Taxonomies

The Anderson-Krathwohl (2001) taxonomy is an upgrade of the behaviorist Bloom's taxonomy which only focussed on teaching and learning in the cognitive domain. As for Anderson-Krathwohl's (2001) taxonomy, the focus is on the cognitive domain as well as the different types of knowledge. In other words, they assert that teachers who wish to understand how learners come to know should be aware of the information (knowledge) students need to acquire and the thought processes that need to be employed to the information. For example, Blooms' taxonomy structures the cognitive processes into six stages of complexity, i.e. Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. On the other hand, Anderson-Krathwohl's taxonomy is structured into six cognitive stages which include: Remember, Understand, Apply, Analyse, Evaluate, and Create, but also the knowledge dimensions which include: Factual,

Conceptual, Procedural, and Metacognitive. Table 6.9 provides a better view of the comparison between Bloom's (1956) and Anderson and Krathwohl's (2001) taxonomy.

Bloom's Taxonomy (1956)	Anderson and Krathwohl Taxonomy (2001)
Knowledge	Remember
<i>Bring to mind important information.</i>	
Comprehension	Understand
<i>Comprehend the meaning of information.</i>	
Application	Apply
<i>Utilize acquired data in novel and concrete circumstances.</i>	
Analysis	Analyse
<i>Chunking of data to comprehend how each piece fit together and understand it as a whole.</i>	
Synthesis	Evaluate
<i>Construct a whole of different parts.</i>	<i>Discern objects based on predefined characteristics.</i>
Evaluation	Create
<i>Estimate the quality of data in line with specific goals.</i>	<i>Construct a whole of different parts.</i>

Table 6.9: Comparison between Bloom's (1956) and Anderson and Krathwohl's (2001) taxonomy.

Examining table 6.9, it becomes evident that on Bloom's (1956) taxonomy continuum, evaluation is at the highest level. The revised version of Bloom's taxonomy, shifts evaluate to the second highest level in the continuum and replaces it with 'create'. Also, the revised taxonomy acknowledges the importance of integrating the cognitive as well as the knowledge

domain, for this reason, Anderson and Krathwohl's (2002) taxonomy also includes the four knowledge domains i.e. factual, conceptual, procedural and metacognitive knowledge.

The rationale for using Anderson and Krathwohl's (2002) taxonomy was to categorize assessment questions based on its degree of abstraction. However, while busy doing just that I discovered limitations within the taxonomy. The revised taxonomy uses verbs to distinguish between different levels on the taxonomy continuum, and since many of the verbs are present at the various levels on the continuum, it becomes a time consuming, complicated process to categorize these questions based on their complexity. For example, the verb '*describe*' is located on two levels of the taxonomy continuum i.e. [Understanding and Remembering]. In other words, appearing on different knowledge levels, it does not explicitly phrase the proposed intricacy. Therefore, invalid inferences would have been drawn from the OMA if only this taxonomy had been utilized. Accordingly, it was decided to use Anderson and Krathwohl's (2002) taxonomy in conjunction with Webb's Depth of Knowledge model (DOK). The next section focusses on the DOK model.

6.21.1.1 Webb's Depth of Knowledge (DOK)

The aim of Bloom's (1956) and Anderson and Krathwohl's (2002) taxonomy was to align curriculum standards, teaching and learning and assessment practices. Accordingly, test items were based on the content that was taught in class. Webb (1999) argues that the assessment items should include both the content knowledge as well as the profoundness in the understanding of content knowledge the teacher wants learners to demonstrate. Webb (1999) developed a DOK model to deal not only with the subject matter being assessed but also the profoundness in presenting an understanding of the subject matter. In other words, the DOK model denotes the complex thought processes that must take place to do an assessment or provide an answer to a test item or do an assignment. Moreover, the DOK model isn't so much as how difficult the item within the assessment is, but the complexity of the thought processes. The text below provides a description of Webb's DOK model.

“DOK -1: Recall and Reproduction: Recall a fact, term, principle or concept, perform a routine procedure.

DOK – 2: Basic Application of Skills and Concepts: Use information, conceptual knowledge; select appropriate procedures for a task; perform two or more steps with decision points along the way; solve routine problems; organize or display data; interpret data; understand or use simple graphs.

DOK – 3: Strategic Thinking: Reason or develop a plan to approach a problem; employ some decision-making and justification; solve abstract, complex or non-routine problems.

DOK – 4: Extended Thinking: Perform investigations or apply concepts and skills to the real world that require time to research, problem solve and process multiple conditions of the problem or task; perform non-routine manipulations across disciplines, content areas or multiple sources” (Hess, Jones, Carlock & Walkup, 2009:4)

The distinction between Anderson and Krathwohl’s (2001) Taxonomy and Webb’s (1999) DOK model is in its application. As for the former, it separates the thinking skills demanded by the brain to complete the task or answer the question on the assessments. “The DOK model, on the other hand, relates more closely to the depth of content understanding and scope of a learning activity, which manifest in the skills required to complete the task from inception to finale” (Hess et al., 2009:4). Essentially this means that the DOK deals with the subject matter that is being tested as well as the profoundness required by students to showcase their understanding of the subject matter. For example, teachers can develop and categorize items in an assessment task according to the DOK model and become aware of what level of understanding learners need to complete the task. Therefore, the DOK relates to the “cognitive complexity” which a task demands of a student and not the difficulty level of the question per se (Hess et al., 2009:4).

Table 6.10 provides an overview of the DOK model, the products associated with each level, the teacher's role as well as potential activities.

DOK model	Description	Products	Teacher's role	Possible activities (math)
DOK - 1	Recall and Reproduce	Test, quiz, facts	Questions, examines, evaluates	Write in own words, basic calculations, simple formula, locating data from tables and graphs, draw, identify, list, state; etc.
DOK - 2	Basic application of skills and concepts	Simulations, journals, linking	Observer, facilitator, examiner.	Construct a model, explain, state a relationship, complex calculations, organize, interpret, identify,
DOK - 3	Strategic thinking	Graphs, animation, video simulation, abstract.	Facilitator, observer, evaluator, examiner.	Create a flow chart, tables, and graphs, formulate, construct,

DOK - 4	Extended thinking	Media product	Facilitator, examiner.	Create a flow chart, tables, and graphs without any guidance, design, connect, analyze, critique;

Table 6.10: The DOK model as integrated with the various functions and roles. [Adapted: Hess et al., 2009:4]

Although the DOK seems promising, I have found that there was no mutual relation between my level of question complexity and those of the DOK model. This discovery was congruent to what Hess et al. (2009) found in their study. Also, I discovered that too many questions are categorized within DOK-1 without measuring learner's conceptual understanding of content knowledge. In other words, integrating Anderson and Krathwohl's taxonomy with the DOK model does not provide you with the means to determine the complex thought processes involved in test item design and development. For this reason, a detailed literature review was conducted in search of a framework to assist the teacher researcher with gaining insights into the thought processes of Deaf and H/H learners. One such framework that proved promising was Hess's (2006b) Cognitive Rigor Matrix (CR). Hess (2006b) was of the view that a CR matrix could be utilized to fill the gap Anderson and Krathwohl and the DOK presents. For this reason, Hess's CR was employed in the current research study.

The next section describes Hess's Cognitive Rigor Matrix.

6.21.1.2 Hess's Cognitive Rigor and Cognitive Rigor Matrix

Since mutual exclusiveness between Anderson and Krathwohl's (2001) Taxonomy and Webb's (1999) DOK model exists, Hess (2006b) provides a possible solution to this inconsistency. He proposed a Cognitive Rigor Matrix (CR) which "vividly connects, yet clearly distinguishes, the two schemata, allowing educators to examine the rigor associated with tasks that might at first glance be comparable in complexity" (Hess et al., 2009:5). For example, asking learners to

perform a single step operation in mathematics are located within DOK-1 and in Anderson and Krathwohl Taxonomy level 3 of the CR. However, using the CR matrix to map the conventional thought processes involved in the mathematics assessment, one can determine in what manner the curriculum is in line with conventional thought processes. Table 6.11 provides an illustration of the CR matrix of Hess (2009).

Revised Bloom's Taxonomy	Webb's DOK Level 1 Recall & Reproduction	Webb's DOK Level 2 Skills & Concepts	Webb's DOK Level 3 Strategic Thinking/ Reasoning	Webb's DOK Level 4 Extended Thinking
Remember Retrieve knowledge from long-term memory, recognize, recall, locate, identify	Recall, observe, & recognize facts, principles, properties			
Understand Construct meaning, clarify, paraphrase, represent, translate, illustrate, give examples, classify, categorize, summarize, generalize, infer a logical conclusion (such as from examples given), predict, compare/contrast, a match like ideas, explain, construct models	Evaluate an expression Solve a one-step problem Represent math relationships in words, pictures, or symbols	Make basic inferences or logical predictions from data/observations Use models /diagrams to represent or explain mathematical concepts	Explain, generalize, or connect ideas using supporting evidence	
Apply Carry out or use a procedure in a given situation; carry out	apply a rule Apply formula Solve linear equations	Select a procedure according to criteria and perform it Retrieve information from a table, graph, or figure and use it	Translate between problem & symbolic notation when not a direct translation	

(apply to a familiar task), or use (apply) to an unfamiliar task		solve a problem requiring multiple steps Translate between tables, graphs, words, and symbolic notations (e.g., graph data from a table) Construct models given criteria		
Analyze Break into constituent parts, determine how parts relate, differentiate between relevant- irrelevant, distinguish, focus, select, organize, outline, find coherence, deconstruct	Retrieve information from a table or graph to answer a question Identify whether specific information is contained in graphic representations (e.g., table, graph, T-chart, diagram) Identify a pattern/trend	Interpret data from a simple graph Extend a pattern	Compare information within or across datasets or texts Generalize a pattern Interpret data from complex graph	
Evaluate Make judgments based on criteria, check, detect inconsistencies or				

fallacies, judge, critique				
Create Reorganize elements into new patterns/structures, generate, hypothesize, design, plan, construct, produce				

Figure 6.11: Hess' Cognitive Rigor Matrix as implemented in this research study [Adapted: Hess, 2006:5]

Figure 6.11 is an illustration of the CR matrix consisting of the DOK levels of the OMA based on the function concept. Essentially this means that the questions within the OMA were developed using the CR matrix. Accordingly, the OMA items tested learning which demanded DOK levels 1 and two on CR matrix. The assessment items were constructed based on the prescribed concepts and skills within CAPS. Accordingly, the highest DOK levels of complexity that CAPS demand is that learners reach DOK level 2 (Skills and Concepts).

This research study tried to go beyond level two and construct questions that required more complex mental processing from users. Hence, the DOK ceiling was pitched at level 3. Petit and Hess (2006) distinguish between the “ceiling of assessment and the “target for assessment” (p.3). Where the ceiling refers to the top level of assessment but including other possible levels of assessment as well. On the other hand, the target relates to assessing only the top level. For the current research study level, three was used as the highest level of assessment, i.e. the DOK ceiling, with level one and two as the possible levels of assessment reaching to the ceiling.

A point to be noted here is that the OMA should not assess content above DOK ceiling level. Petit and Hess (2006) argue that by doing the latter, it might provide teachers with meaningful data to adjust their teaching and assessment practices. They further posit that a useful protocol is to assess one level below the DOK ceiling level which might also guarantee some useful information for teachers.

Table 6.12 illustrates the DOK ceiling level of the current research project as well as the possible levels of assessment leading up to the ceiling level.

Concepts and Skills prescribed by CAPS	DOK Ceiling	Level for OMA
<p>“Input and output values</p> <p>Determine rules for patterns and relationships using: flow diagrams, tables, formulae, and equations.</p> <p>Equivalent forms</p> <p>Determine, interpret and justify equivalence of different descriptions of the same relationship or rule presented: verbally, in flow diagrams, formulae, equations, graphs” (DoE, 2011:22).</p>	3	<p>DOK Level 1</p> <p>Recall and Reproduce rules and relationships</p> <p>DOK Level 2</p> <p>Applying skills and concepts relating to the function concept</p> <p>DOK Level 3</p> <p>Thinking and Reasoning about the function concept</p>

Table 6.12: An illustration of the DOK levels for the OMA

Table 6.12 illustrates the continuum of learning that took place within the OMA. A point that needs to be noted is that although DOK level 3 is the highest level of cognitive demand, the assessment didn't start and end at that level. The reason for this was that the OMA would be too difficult for all participants and the learning that took place while users were engaged with the OMA would have gone to waste. Accordingly, the items within the OMA based on the function concept were constructed to create space to observe the learning as it occurred within each user.

A representation of the concentration of questions and its levels of complexity will now be illustrated to highlight what kind of cognitive complexity the content demanded.

Online Mathematics Assessment of Grade 8 Deaf and H/H learners

Anderson and Krathwohl's Taxonomy	1	4%			
	2	10%	8%	2%	
	3	20%	18%	2%	
	4	12%	14%	8%	
	5				
	6			2%	
		1	2	3	4
	Hess's Depth of Knowledge				

Table 6.13: Cognitive rigor of Deaf and H/H Grade 8 learners based on the OMA.

The table illustrates that the questions within the OMA reached the highest level of the Revised Bloom's Taxonomy, level 4 (Analyze) and the highest DOK level, level 3. The largest concentration of questions was pitched in Anderson and Krathwohls' taxonomy at level 3, DOK 1, followed by level 3, DOK 2, while the overall highest concentration of questions was found in Anderson and Krathwohls' taxonomy level 1 to 4 and DOK level 1. Although it can be argued that this phenomenon points to the teacher encouraging surface learning, I maintain that through a deeper understanding of basic function concept, transfer (DOK level 2 and 3) might occur.

The participants found it difficult to answer both DOK 1 and DOK 2 level questions specifically during Plan 1. However, this situation changed as more modification were done to the OMA. This resulted in an improvement in performance on test scores during Plan 2 and Plan 3. In other words, it can be noted that as the users' depth of knowledge increased, so did their performance on the OMA.

Observing DOK level 2, 40% of the OMA items covered content at this level, which means that these questions were more challenging and demanded more cognitive complexity. The questions within these level demand users to move between representations of the function concept, to

construct models of the function concept i.e. flow diagram, table, graph, interpret a graph and to retrieve information from different representations of the function concept. At first (Plan 1) users found it tough to answer these type of questions. They either left it blank or incorrect. However, as their understanding increased and as modifications to the OMA were made (Plan 2 and Plan 3), they could answer these type of questions and hence transfer their acquired knowledge to new situations.

However, evaluating DOK level 3, it can be observed that only 12% of the overall OMA items covered this level. In other words, the cognitive complexity associated with this DOK level isn't sufficiently accommodated by the test items. Also, users found it difficult to answer these type of questions due to the challenging nature of these questions. However, as the depth of their understanding increased, they could eventually respond to these difficult questions as can be seen, from Plan 3's test results.

The next section focusses on the facets and layers of the function concept.

As discussed in Chapter 2, the framework of DeMarios and Tall (1999) specific to the function concept as represented by facets and layers were utilized in the current research project. As for the facets, it included the function machine (colloquial), symbolic representation (algebraic formulae), numeric representation (table), geometric (graphic) and written and verbal representation. On the other hand, the layers included the pre-procedure, procedure, process, object and procept (DeMarios & Tall, 1999). A profile of each learner in the Grade 8 class was constructed based on their answers in the OMA

Further analysis of the replies to each question in the OMA based on the function concept revealed the following results. All the learners' responses were analyzed, and DeMarios and Tall's (1996) facets and layers model were used to depict the current state of students' understanding of the function concept. Each students' model throughout Plan 1 to Plan 3 will now be illustrated and discussed below.

Users were asked to respond to questions posed on the function concept within the OMA. The questions included the following:

- Translating from a symbolic to a numeric, function machine, graph and written representation;

- Translating from numeric to symbolic, function machine, graph, and written representation;
- Translating from a function machine to symbolic, numeric, graph and written representation;
- Translating from a graph to a symbolic, numeric, function machine and written representation;
- Translating from written representation to symbolic, numeric, function machine and graph.

6.21.1.3 User understanding of the function concept

User 01

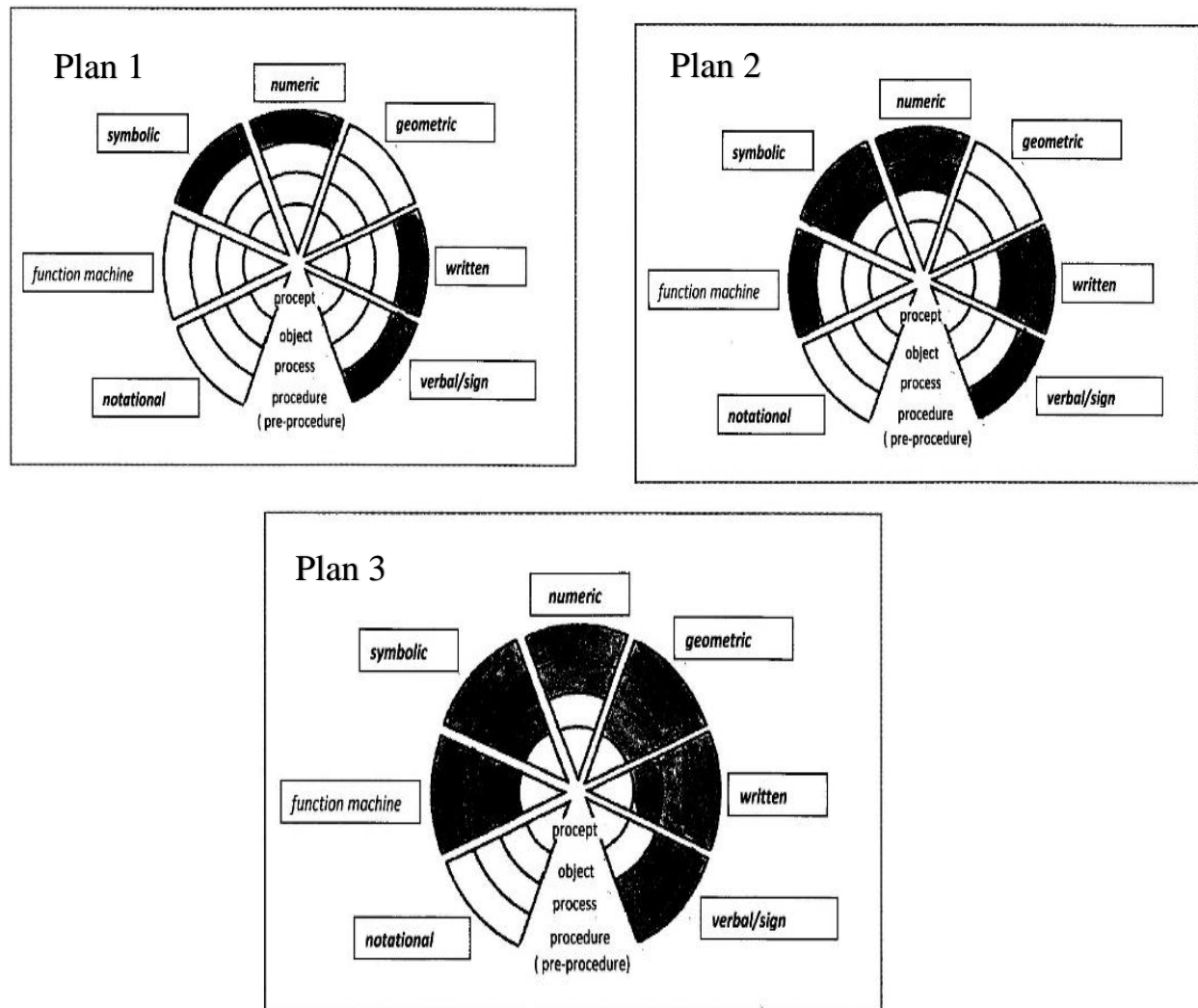


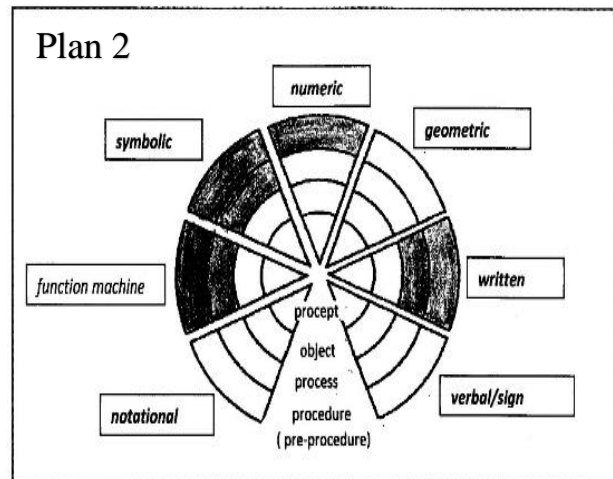
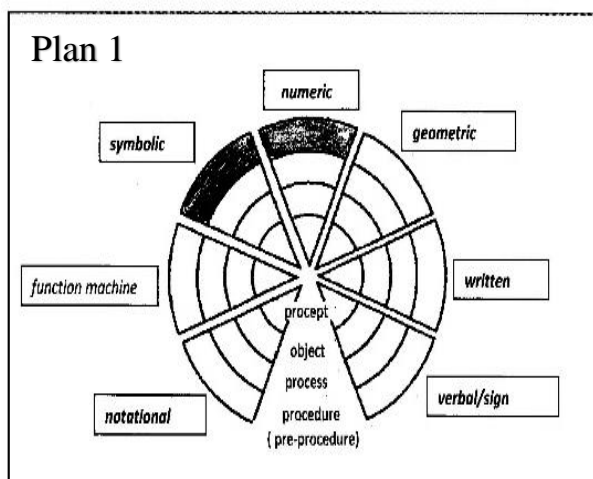
Figure 6.27: An illustration of the facets and layers model of user 01

The figures above are pictures of user 01's understanding of the function concept. Each figure depicts the users' understanding during the particular plan. During Plan 1, user 01 was able to translate from symbolic to numeric as well as from written to symbolic and numeric. However, this user was unable to translate from numeric to symbolic as well as from the function machine to symbolic or a graph. Essentially this means that user 01 was comfortable in answering questions when presented with an algebraic formula as opposed to drawing a graph from a function machine.

Studying Plan 2, there was an improvement in this users' understanding since the user moved from the procedure layer to process layer for symbolic, numeric and written representations. The illustration depicts that user 01 could answer questions when presented with symbolic, numeric and representations of the function concept and that the user could translate between these representations. Also, during plan one this user couldn't answer questions based on the function machine but that changed as well since this user could now move from a function machine to a numeric representation. It can thus be noted that due to modifications made to the overall OMA based on the function concept, the users' understanding improved.

Also, observing Plan 3 it becomes apparent that this user reached a better understanding of the function concept. This user moved from the process layer to the object layer for the function machine, symbolic, geometric and written representations. However, the user never reached the precept level.

User 02



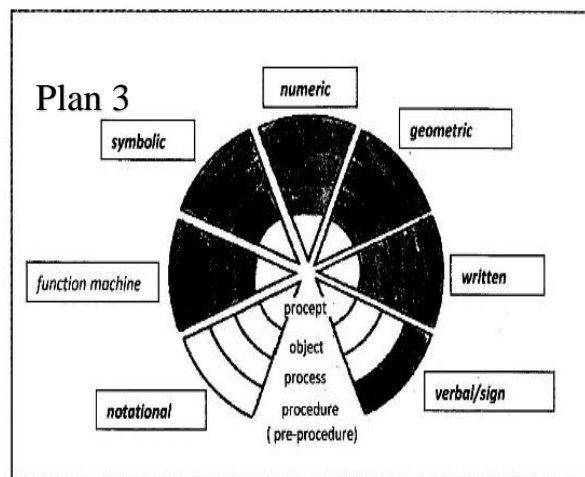


Figure 6.28: An illustration of the facets and layers model of user 02

User 02 had problems from the start. This user could only move between numeric and symbolic representations of the function concept. Questions based on other representations, the user either left blank or got it wrong. It can thus be noted that this user was still on the pre-procedure layer in relation to the other representations.

Plan 2, on the other hand, indicates an improvement in this users' understanding of the function concept. Not only could this user answer questions based on the function machine and provide a numeric and written representation of the function concept but the user could also translate between symbolic and written representations. Also, for symbolic and written representation and the function machine, this user moved from the procedure layer to the process layer.

Plan 3 depicts a vast improvement in this users' understanding of the function concept. This user moved to the object layer for all the representations of the function concept. In other words, due to the adaptations of the OMA based on the function concept, the user was able to grasp the function concept better than the previous two plans.

It should be noted that this user did not reach the procept layer which remains a concern and something to keep in mind for further improvements.

User 03

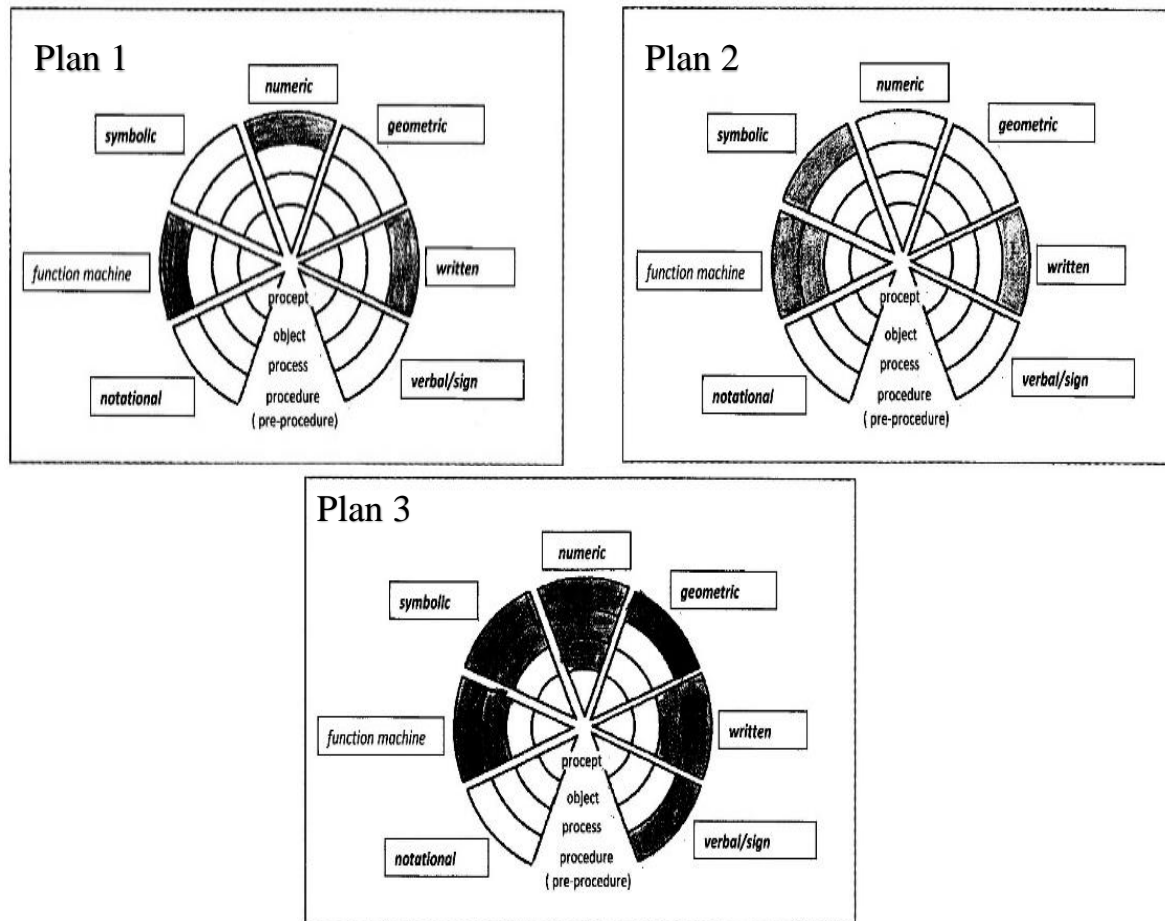


Figure 6.29: An illustration of the facets and layers model of user 03

User 03 could only translate between the function machine and numeric representation of the function concept. This user could also provide a written representation of a numeric representation when asked to do it. However, this user was unable to provide a symbolic answer to a numeric question as well as a numeric answer for a symbolic representation. This user also struggled to interpret a graph from a function machine.

Observing Plan 2, one can notice that very little improvement occurred. This user was only able to provide a symbolic answer when posed with a function machine. Every other representation except the function machine stayed on the same layer which means that this users 'understanding of the function concept didn't improve.

Plan 3 provides a somewhat different perspective, and it seems that this users' understanding did improve. Looking at the symbolic, written, numeric and function machine, one can see that a

movement from the procedure to the process layer occurred. Also, a shift from the procedure to the object layer occurred for numeric representation which is an indication that this users' understanding of the numeric representation of the function concept improved a lot.

User 04

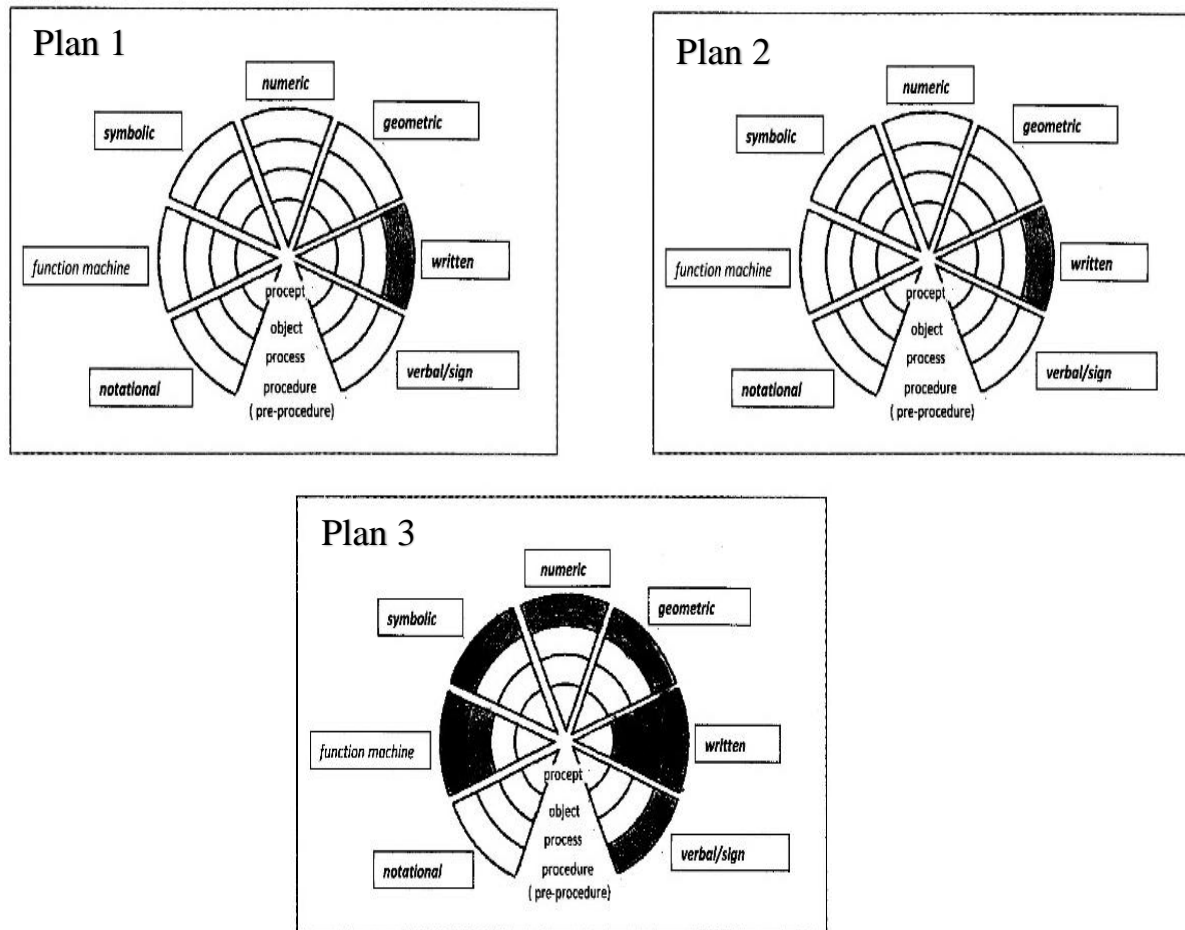


Figure 6.30: An illustration of the facets and layers model of user 04

User 04 had significant difficulties grasping the function concept. During Plan 1 this user could only translate between written and symbolic representations of the function concept. This user was unable to move between other representations of the function concept when asked to do so. Although adjustments were made during Plan 2, it did not help this users' understanding of the function concept which was somewhat disturbing giving the fact that it helped the previous users.

During Plan 3 there were somewhat improvements, especially while engaged with the function machine and the written representation of the function concept. As for the written representation, this user moved to the object layer and for the function machine, the user moved to the process layer. However, for all other representations, this user stayed on the procedure level. Although an improvement was noticed when compared to the other plans, it is still concerning.

User 05

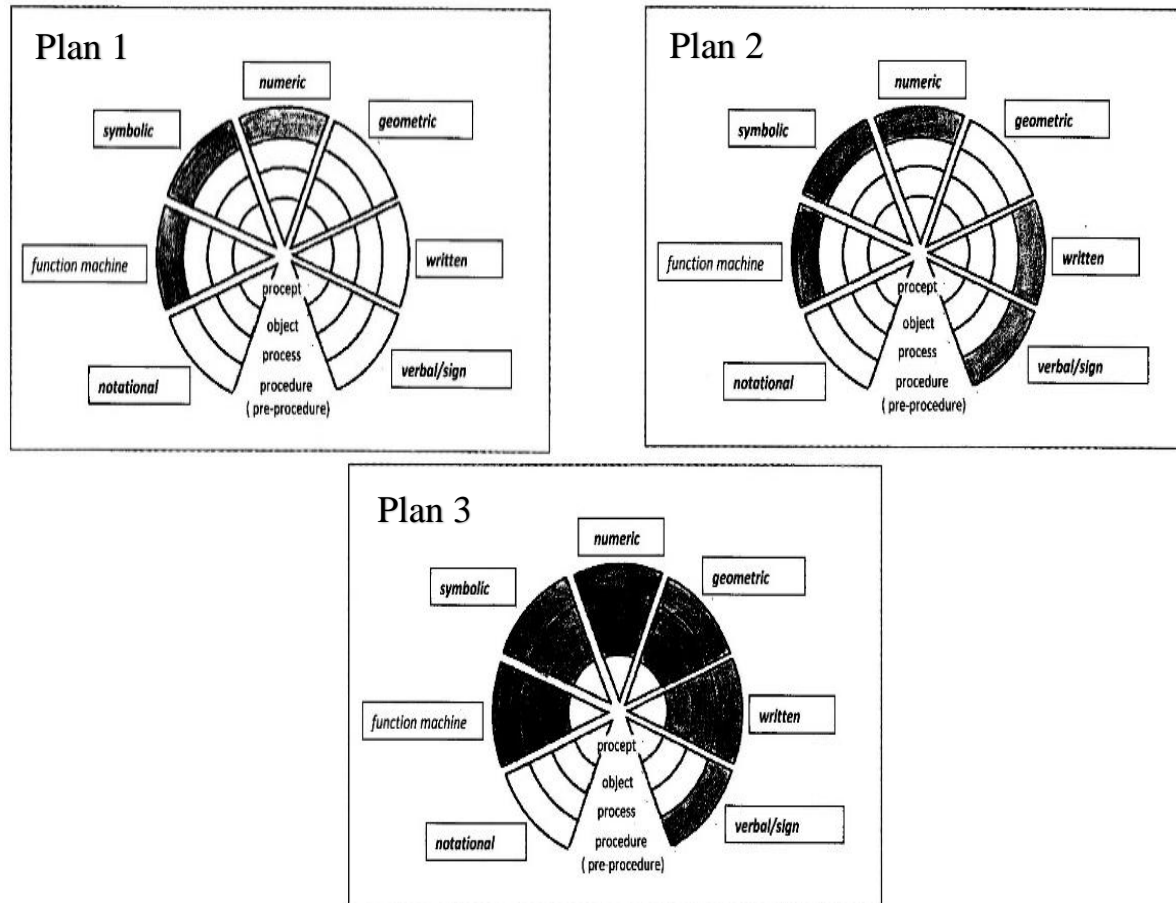


Figure 6.31: An illustration of the facets and layers model of user 05

User 05 could translate between symbolic and numeric as well as function machine and symbolic. However, this was only at a procedure level. This user was unable to answer questions based on written and geometric representations.

This user's understanding of the function concept improved during Plan 2. This user could translate between written and symbolic and symbolic and written representations of the function concept. However, user 05 was unable to move from the procedure layer.

This user's understanding improved completely during Plan 3. Not only did user 05 progressed from the procedure layer to the object layer for the different representations of the function concept but the user could also construct a graph from the function machine. The user could also move back and forth between all representations of the function concept.

User 06

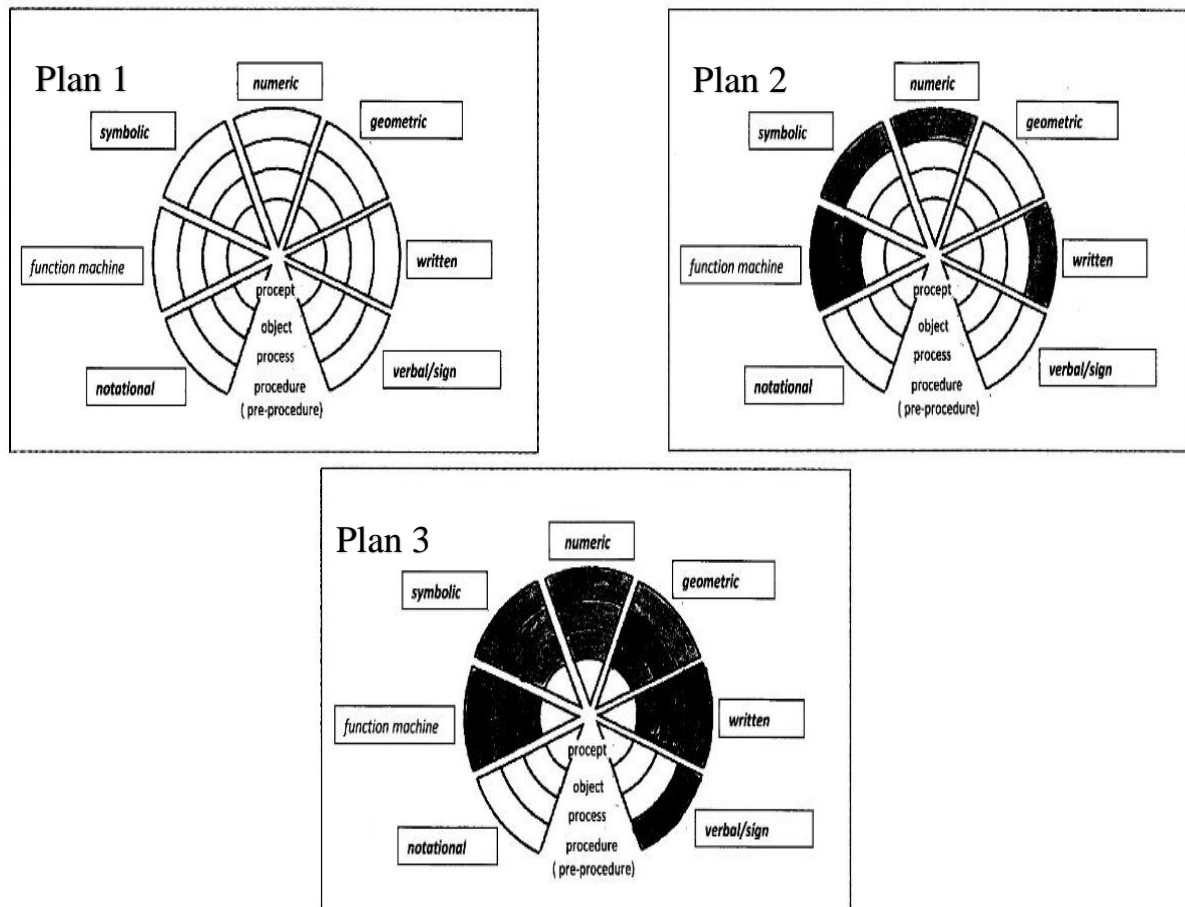


Figure 6.32: An illustration of the facets and layers model of user 06

User 06 was a huge concern during Plan 1. This user could not translate between any of the representations of the function concept. Not only did this user struggle to interpret the questions but the user lost interest while struggling to answer the questions.

The users' understanding improved during Plan 2 after adjustments were made to the original OMA. While user 06 was still on the procedure layer for symbolic, numeric and written representations of the function concept, the user moved to the process layer with the function machine.

A vast improvement in this users' understanding was observed during Plan 3. For all the representations of the function concept, the user moved to the object layer. In other words, from a limited understanding of the function concept and its different representations to an improved understanding. This user was also one of the participants who scored 100% on the final OMA.

User 07

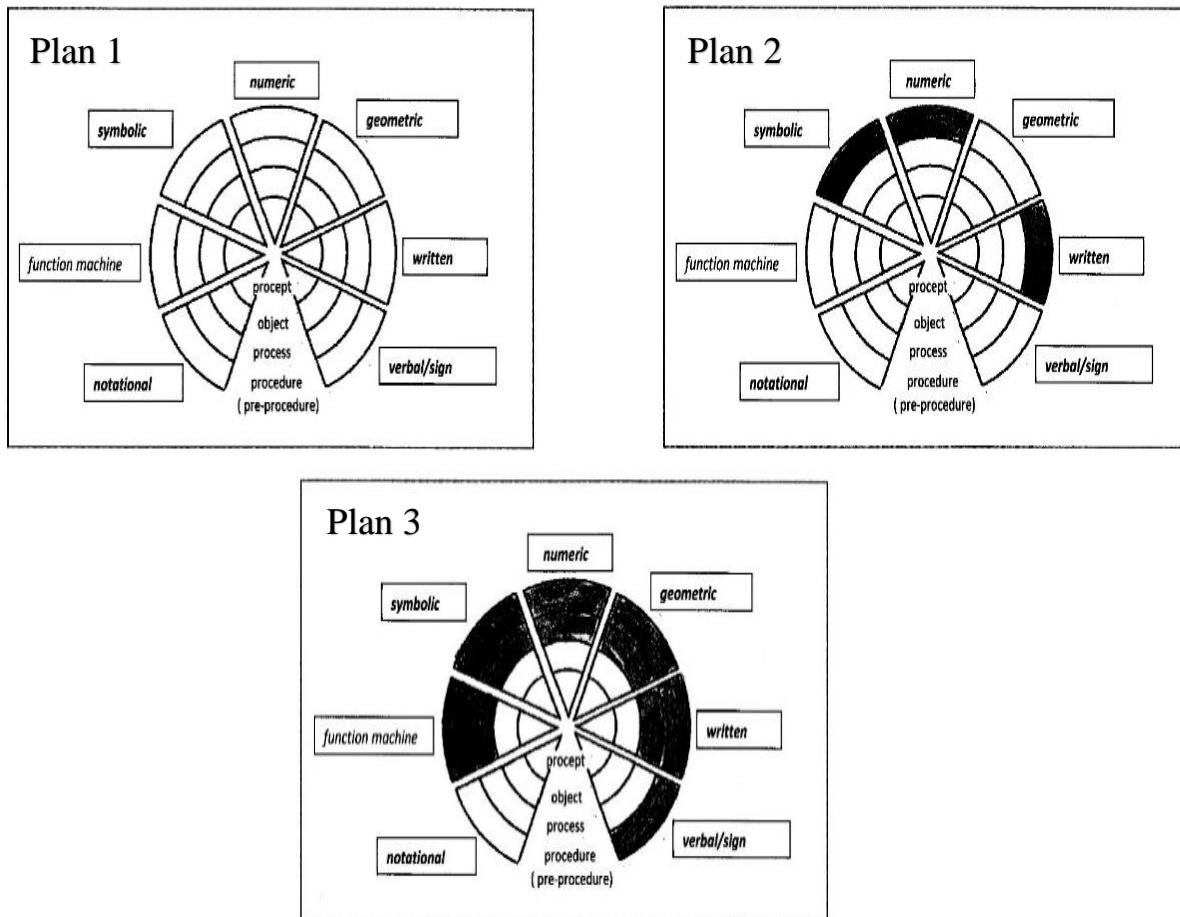


Figure 6.33: An illustration of the facets and layers model of user 07

User 07 struggled to grasp the function concept and therefore couldn't translate between the different representations thereof. This user was still on the pre-procedure layer with all the different representations of the function concept.

An improvement in the users' understanding was noticed in Plan 2. While this user could only translate between numeric and symbolic as well as written and symbolic, the user was unable to

move from the procedure layer. User 07 was also unable to translate between the function machine and a graph.

Improvements in the users' understanding of the function concept during Plan 3 was observed. The user could move between numeric, symbolic, written and graph as well as the function machine. Also, a movement from the procedure layer to the process layer was observed which further indicates an improvement in this users' understanding of the function concept.

User 08

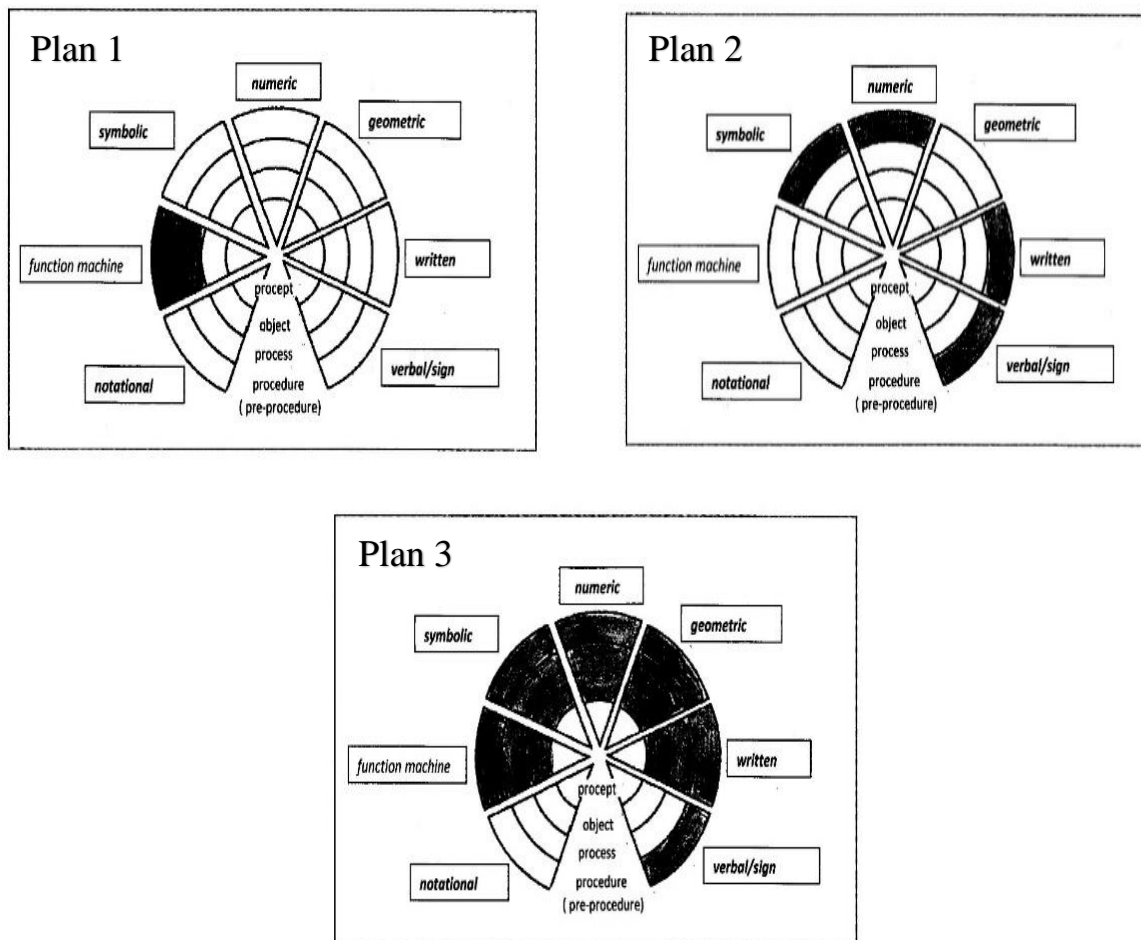


Figure 6.34: An illustration of the facets and layers model of user 08

User 08 found it difficult to translate between all representations of the function concept except the questions based on the function machine. Also, the user started off in Plan 1 on the process layer.

This user could translate between symbolic, numeric and written representations during Plan 2 which indicates an improvement in the users' understanding of the function concept. However, the user only reached the procedure layer within Plan 2. Significant improvements in this users' understanding of the function concept occurred during Plan 3. The user's understanding moved from procedural to object layer and can, therefore, be regarded as an improvement in the users' overall understanding of the function concept.

The facets and layers model of all eight users indicate that most of them (N=6) started Plan 1 on the procedural layer. Only two users started Plan 1 on the pre- procedure layer. However, as modifications to the original OMA based on the function concept occurred, their understanding improved and they could move from the procedure layer to as far as the object layer. Also, as adjustments were made to the OMA, the user could more easily translate between the different representations of the function concept. Although no user progressed to the precept layer, there were still indications of improvements from the pre-procedure to the object layer.

6.21.1.4 Summary

This section of the research paper tried to answer the question: *What characteristics should online mathematics assessment adhere to in order to provide mathematics teachers with insights into the cognitive functions and dysfunctions of Deaf and H/H learners?* During the observation and interview session, it was found that a mere right or wrong answer didn't provide the teacher researcher with enough evidence to perceive what's going on in the mind of the learners.

Although the OMA items were constructed in line with the curriculum framework (CAPS), it still wasn't enough to gain insights into the cognitive functions of Deaf and H/H learners. As a result, Webb's DOK and Hess's CR model had to be employed to assist the teacher with this challenging task.

Constructing the OMA items in line with the CR matrix provided the teacher researcher with useful insights into the cognitive functions and dysfunctions of Deaf and H/H learners. Not only could the teacher researcher construct the OMA items based on its complexity, but it also indicated the cognitive demand of the test items. Therefore, the deduction could be made based

on how the learners answered the questions and at what level on the CR matrix they operate. Although most of the learners performed at level one, especially during Plan 1, modifications to the OMA resulted in moving from level one to level two and even level three. In other words, the teacher researcher could observe an improvement in the way learners recall content, interpret and translate between different representations of the function concept and how they applied what they learned in other novel situations.

Therefore, it can be argued that aligning test items to curriculum outcomes alone is not a guarantee that deep learning will take place. Teachers have to look at the cognitive rigor of content and ensure that the subject matter extends over all four levels of the CR matrix.

A useful discovery was the way in which the modifications to the OMA assisted learners in constructing their knowledge. During Plan 1, all of the Deaf and H/H students struggled to grasp what was asked of them but as modifications were made and as the mediation increased, their knowledge was altered.

The next section focuses on answering question two of this research study.

To respond to the second research question which is: *How can the use of online mathematics assessment as an alternate assessment mediate the learning process of Deaf and H/H learners*, it was necessary to bring it in line with Feuerstein's (1988) Mediated Learning Experience (MLE) to investigate potential of OMA as a mediator of the learning process of Deaf and H/H learners. Each of the characteristics of MLE as it was discussed in Chapter 3 was utilized and incorporated within the OMA.

6.21.2 Mediated Learning Experience

The following section includes the features of MLE as suggested by Feuerstein (1988) and how it was implemented within the current research project.

6.21.2.1 Intentionality and reciprocity

The Deaf and H/H Grade 8 learners had a hard time interacting with the OMA, the first two times (Plan 1&2) they were presented with it. The obstacles they experienced became apparent from the answers during the first and second interview session. Although they had experience with LMSs, answering the test items presented obstacles that demotivated them. For this reason, the teacher researcher had to construct certain interactive activities as part of the online mathematics assessment. The teacher, on the other hand, posed questions, while they were interacting with the mathematics simulations. These questions were aimed at guiding them in discovering certain concepts and ideas. For example, engaging with the function machine, they could deduce that there must be input and output values and that something happens to the input or output value in between. Later on, they started using words (signs) like the rule, formula, table, graph, x value, y value, etc. Figure 6.35 is an illustration of one of the interactive questions included in the OMA.

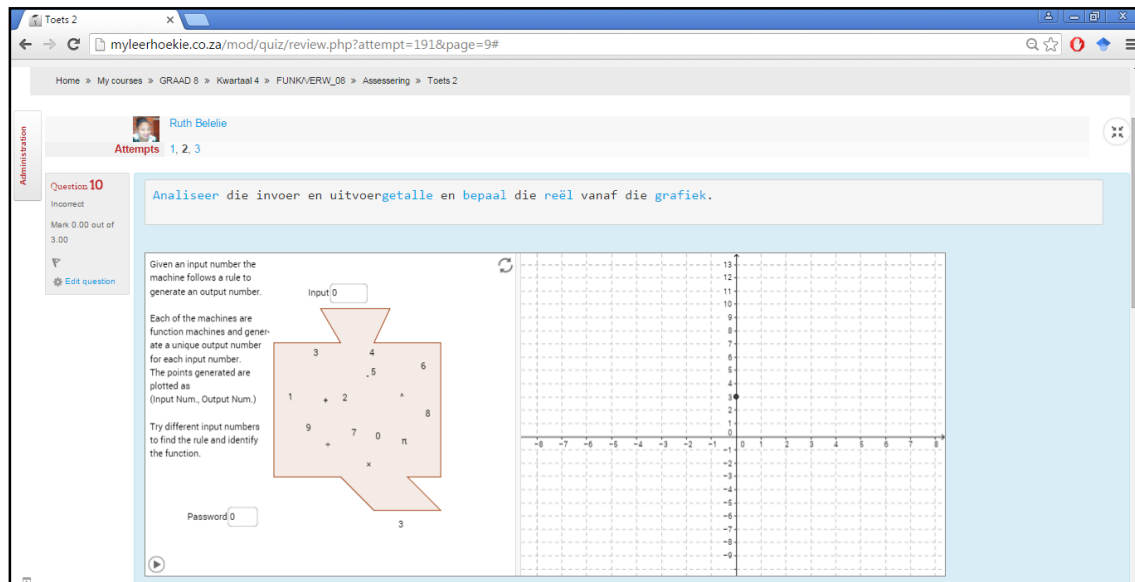


Figure 6.35: An example of an interactive question type included in the OMA

6.21.2.2 Transcendence

As stated in chapter 3, transcendence is a means of transferring accumulated knowledge to new situations. This characteristic was achieved through questioning. This was done through the active quiz module in Moodle. Learners were divided into groups of two playing against each other. Each time a team answered a question, the teacher researcher asked a question like why they opt for that answer, explain your answer and what they can deduct from a particular answer and apply it to the next. Greenberg (2005) posits that questioning can assist learners in zooming in on the learning process and not so much as telling students. On the other hand, King (1994) argues that guided questioning can assist students in knowledge construction and draw links between prior knowledge and new found knowledge. In other words, through specific questioning, Deaf and H/H students could discover and understand solutions to problems, hence assisted them in their knowledge construction.

6.21.2.3 Mediation of Meaning

This characteristic of MLE involves creating learning opportunities that are useful and of interest to the learners. This feature became apparent through the interview sessions with each Deaf and H/H student. The answers students provided during the interview sessions was used to modify the format and content of the OMA to accommodate each learners' needs. For example, most of the learners had a problem with text. The text was adjusted to include signs and illustrations which they could understand. Moreover, some of the learners enjoyed the interactive content, therefore more interactive content was added to the quizzes. In other words, not only did the teacher researcher adjust the difficulty level of the OMA, but it was modified in line with the learners' needs. Also, a lot of thought went into the presentation of the content within the OMA, so that it fits into the way Deaf and H/H learners learn and the best way they can provide their answers. Moreover, an appraisal element was also added to the quiz to appraise students for their achievements thus far and to motivate them to complete each quiz. Figure 6.36 is an illustration of mediation of meaning feature that was integrated within the OMA.

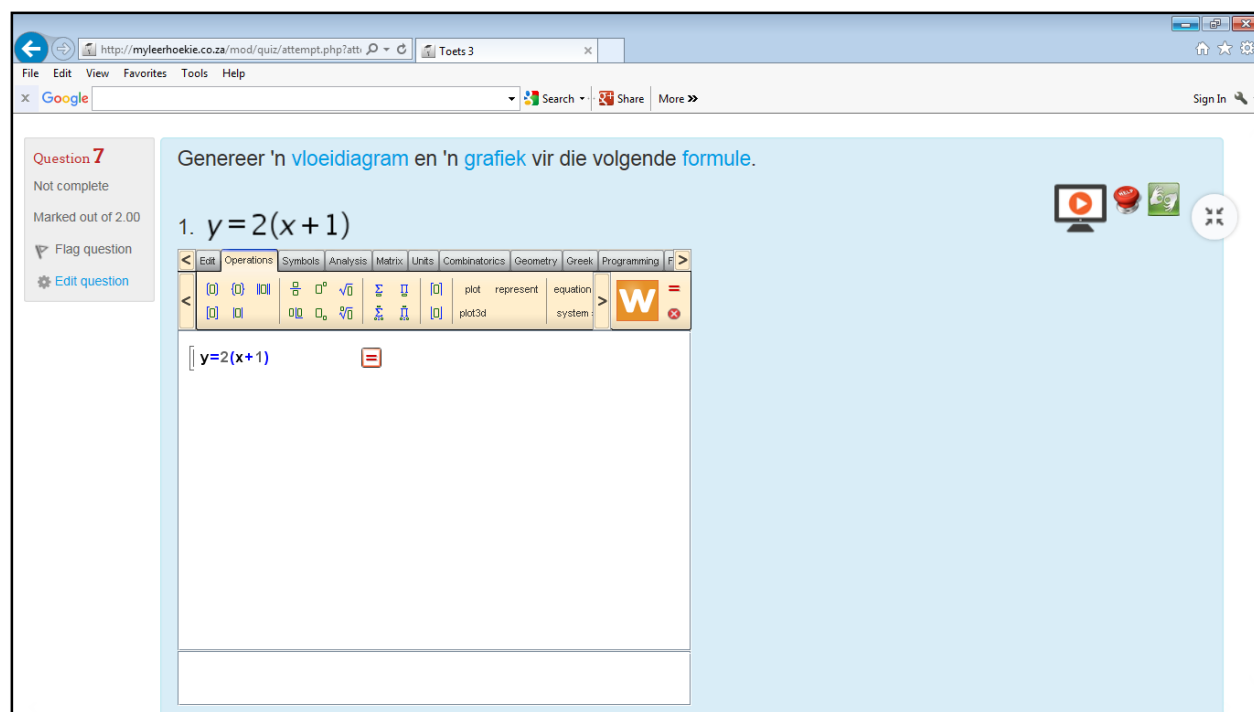


Figure 6.36: An example of mediation of meaning incorporated into the OMA

6.21.2.4 Mediation of confidence

Mediation of confidence entails developing learners' self-confidence for them to become more autonomous learners. This was achieved through general and specific feedback after submitting a question. When students receive a PPA, it is usually marked in red i.e. an x for the incorrect answers and a check mark for the correct answers. The answer sheet of learners that didn't do so well on the assessment is usually cluttered with red X's which can demotivate students since it focusses their attention more on what they got wrong than right.

In contrast to what is happening with PPA, general and specific feedback can be given in OMA. For example, when learners submit their answers for marking, a wrong answer will activate a specific feedback, which in the current research study makes use of video feedback. This feature does not focus on the mistakes learners made but provides them with similar problems and how they can solve it. The feedback is aimed at assisting students' understanding in addressing similar problems to empower them to go back and fix what they did wrong. Moreover, students obtained badges for completing difficult parts of the activity. Not only did it provide healthy

competition between each other but it also provided some motivation to keep at it no matter how complicated it gets (see figure 6.37 below). Seng (1997) posits that by empowering learners through developing their self-confidence can assist them in independent thought processes and motivates them towards goal orientated action.

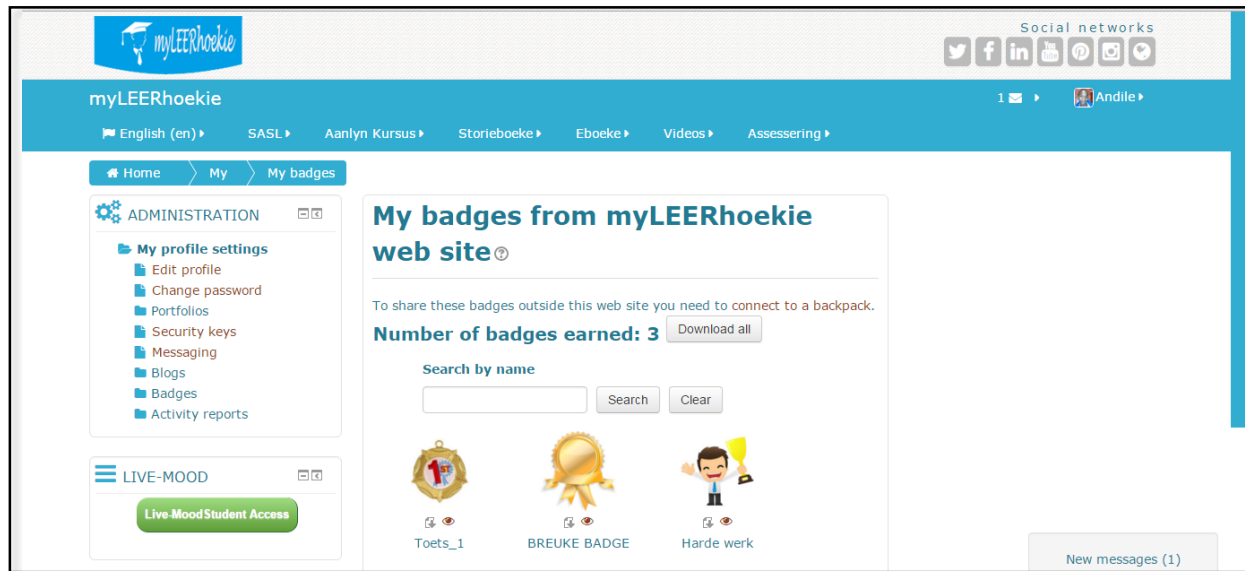


Figure 6.37: Badges linked to the OMA in Moodle

6.21.2.5 Mediated regulation and control of behavior

This characteristic of MLE involves assisting the learner to examine each problem and adjust their approach to the problem. This was achieved within the current research project by chunking difficult concepts into manageable pieces. For example, providing learners with interactive simulations within the quizzes on one aspect of the function concept such as the function machine. When they were competent with the function machine, they were able to tackle more complex problems such as moving between the function machine and graphs.

Accordingly, successes with the function machine motivated Deaf and H/H learners to try out more complex problems with the function machine and hence taking responsibility in his/her learning process. Also, by including multi-part questions accompanied by illustrations that learners could analyze and extract answers also assist them in their understanding of difficult

concepts. Figure 6.38 is an example of how mediated regulation and control of behavior was integrated within the OMA.

Question 1
Not complete
Marked out of 4.00
Flag question
Edit question

Bestudeer die tabel en beantwoord die vrae.

Invoergetal	1	6	9	12	18	20
Uitvoergetal	1	36	81	144	324	400

a) Wat sal die uitvoerwaarde van 30 wees?

☐ 900
☐ 700
☐ 400
☐ 500
☐ 300

b) Indien die uitvoerwaarde 225 is. Wat is die invoerwaarde?

c) Indien die invoerwaarde 22 is, wat sal die uitvoerwaarde wees? ...

Figure 6.38: An example of mediated regulation and control of behavior embedded into the OMA

6.21.2.6 Mediated sharing behavior

This characteristic involves creating opportunities for both teacher and learner to exchange ideas and opinions to develop trust and cooperation. This feature of MLE was achieved through acknowledging students' response as valuable and not imposing my ideas on them. In other words, listening to each other. For example, their answers during the interview sessions were used to adapt the content of the OMA. This provided them with an awareness that their voices are being heard and that their ideas are valuable within the learning process. It also provided a trusted environment where they could easily raise their concerns relating to obstacles or successes they experienced.

6.21.2.7 Mediation of individuation and psychological differentiation

This feature entails the acknowledgment of diversity in every classroom. In other words, each learner is different from the rest of the class and therefore require different teaching and learning approaches. For this reason, various formats of the same question within the OMA exists.

Essentially this means that the OMA catered for each learners' learning preference i.e. video, simulations, text, illustrations, etc. From the interviews that were conducted, it became apparent that not one student felt excluded within the OMA.

Question 2
Not complete
Marked out of 4.00
Flag question
Edit question

Bestudeer die vloeiagram en beantwoord die vrae.

3
a
1
0
-1
b
c

8
d
7
e
4
f
g

+ 5

a) In die verwantskap van die vloeiagram, stem die uitvoergetal

☐ 11
☐ 5
☐ 9
☐ 7
☐ 8
☐ 4

ooreen met die invoergetal -1.

b) Die invoergetal stem ooreen met die uitvoergetal 7.

c) Indien dit as 'n invoergetal gewys was, sou jy kon sien dat met die uitvoergetal 31 ooreen stem.

d) Indien die invoerwaarde van c 122 is, sal die uitvoerwaarde wees.

Figure 6.39: An example of mediation of individuation and psychological differentiation within the OMA

Although all the learners have access to the same representation of the questions, they can

choose from the three icons on the right [] which will present them with either a video representation, Sign Language or help in the form of a step by step guide.

6.21.2.8 Mediation of goal seeking, goal setting, goal planning and achieving behavior

This characteristic involves motivating learners to set goals they can achieve. Since the goal with the OMA was to modify students' cognitive structures, the quizzes were broken down into smaller achievable goals with the end in mind. All in all, the students worked towards the primary aim by accomplishing smaller goals along the path. For example, firstly, learners had to master the function machine and then use the rule to complete a table based on the function machine. Afterward, the learners had to rewrite the rule in words, present it by making use of a formula and then translate it to a graph.





Infos		Ladder			
Rank		Full name	Level	Experience points	Progress
1		Marochelle Grove	2	150	<div><div></div></div> 30/156
2		Ruth Belelie	2	141	<div><div></div></div> 21/156
3		Andile Kiewiets	1	48	<div><div></div></div> 48/120
4		Noluthando Hendricks	1	27	<div><div></div></div> 27/120

Figure 6.40: An illustration of mediation of goal seeking and goal setting within the OMA

This feature within the OMA was extremely useful since learners gained experience points based on their interactions with the overall course based on the function concept. Their experience points allowed them access to Plan two's OMA as well as Plan three. This meant that low experience points denied them access to the OMA in other Plans.

6.21.2.9 Mediation of challenge: The search for novelty and complexity

Learners should be encouraged to accept straightforward and challenging problems with equal enthusiasm. This feature was accomplished within the current research project by not only presenting students with simple questions based on the function concept but also complicated problems. Although the OMA start out with simple questions to encourage students, it increased in complexity the higher the learners progressed. Also, since randomized questions were used, it

also increased the complexity of the questions. Accordingly, by presenting students with simple problems first, they might overcome their fear for more complex problems. In other words, they become more committed and keen to take on more challenging questions. Figure 6.41 is an illustration of one of the most complex problems learners had to answer.

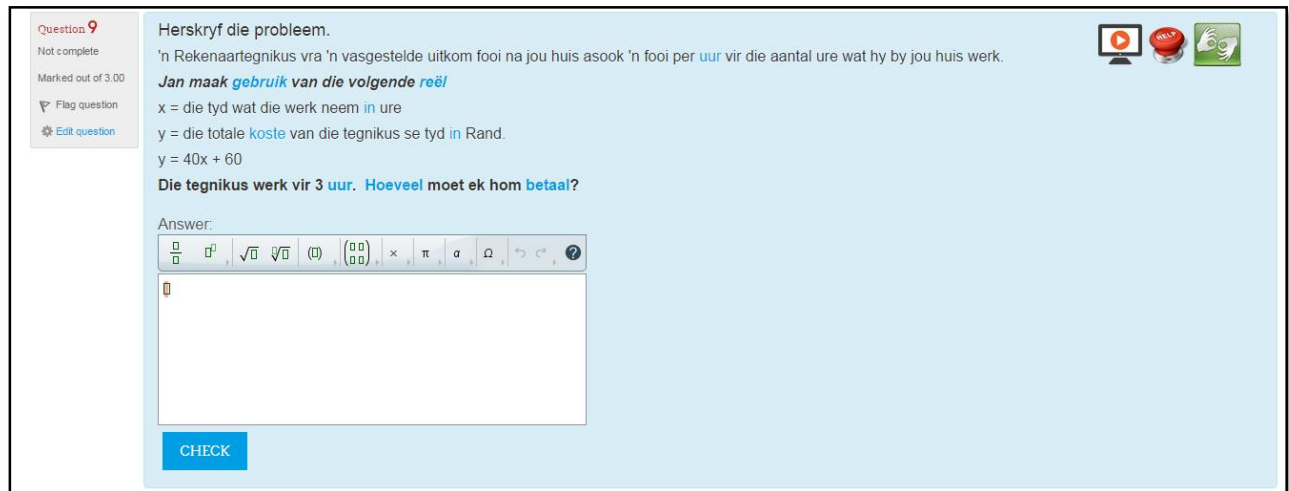


Figure 6.41: An example of one of the most complex problems learners had to answer

6.21.2.10 Mediation of an awareness of human being as a changing entity

This characteristic entails making students more aware of how changes occur within them and that these changes can be for their benefit. This feature was accomplished within the current research project using self-reflection. Through the use of a journal, learners could become aware of how their thought processes changed towards the OMA. It also made them focus on their successes they developed from their very first interactions to their final interactions i.e. from not being competent to answer even one question to being capable of achieving (100%) in an OMA.

6.21.2.11 Summary

In trying to respond to the question: *How can the use of online mathematics assessment as an alternate assessment mediate the learning process of Deaf and H/H learners*, it was discovered that the OMA has the potential to mediate the learning process of Deaf and H/H students.

Through the utilization of Feuerstein's (1988) MLE and integrating it within the OMA, it could assist Deaf and H/H students with their understanding based on the function concept.

On the one hand, learners could use the built in mediation elements to adjust their understanding based on the function concept. On the other hand, the mediation features of the OMA developed autonomy in learning since they could choose which representation of the problem they prefer and learn from it. It follows then that knowledge construction occurred as a result of an increased mediation.

An essential element that surfaced was the learner as a mediator. Students with a sound understanding of the function concept were used in some of the videos to guide other students in their understanding of the function concept. Also, while engaging in the practice mode of the OMA, pupils were discussing some of the questions and throwing around ideas on an approach to a particular problem. This endeavor had significant successes for other students who grappled with the function concept. As a result of these collaboration efforts, more modifications were proposed by students.

The next section focuses on answering question three of this research study.

To respond to the third part of the research question, which is: *what are the operational implications of online mathematics assessment for Deaf and H/H learners as well as for teachers?*

6.21.3 Operational challenges of OMA

This section of the research paper focuses on the operational challenges related to administering OMA in schools for Deaf and H/H learners. More specifically, the discussion focuses on whether the school facilities, hardware, software, network infrastructure and other peripherals are sufficient to conduct OMA. Since this research study was done making use of Moodle, WIRIS, and GeoGebra, certain requirements were in need of attention before these products could be utilized. The section concludes with the operational implications for teachers and learners. What follows is the minimum system requirements to run Moodle, WIRIS, and GeoGebra.

6.21.3.1 Software requirements

Table 6.14 below illustrates the database servers Moodle supports. A database server is a product that manages and stores information. Please be advised that the version number is only the minimum system requirements to run Moodle.

Database	Minimum version	Recommended
PostgreSQL	9.1	Latest version
MySQL	5.5.31	Latest version
MariaDB	5.5.31	Latest version
Microsoft SQL Server	2008	Latest version
Oracle Database	10.2	Latest version

Table 6.14: Minimum and recommended database server requirements [Adapted: Moodle, 2016]

From the above table, it becomes apparent that the latest database server is highly recommended for Moodle to install.

6.21.3.2 Web browser prerequisites

To actually run Moodle on your computer, you need a web browser that supports the Moodle version. A web browser is a software application which can be used to recall, present, and pass data over the World Wide Web. The requirements in Table 6.14 are only prerequisites to install the software on the server side. The client-side requirements are illustrated in Table 6.15 below.

Web Browser	Minimum version	Recommended
Google Chrome	30.0	Latest version
Mozilla Firefox	25.0	Latest version
Apple Safari	6	Latest version

Microsoft Internet Explorer	9	Latest version
-----------------------------	---	----------------

Table 6.15: Client-side Web browser requirements [Adapted: Moodle, 2016].

6.21.3.3 GeoGebra prerequisites

There are three options to choose from in order to install GeoGebra. You can choose to run it through your web browser by using Webstart, or you can install it on your standalone computer. However, using the second option you need to install the latest JAVA version. JAVA is a “programming language and computing platform” (java.com, 2016:1) that you need to install on your computer to run different programs and applications. The third option is to install the GeoGebra plugin directly into Moodle. This option was used within this research study i.e. the GeoGebra quiz plugin was directly installed within Moodle and accessed from the Moodle site.

6.21.3.4 WIRIS prerequisites

WIRIS can be used as a standalone desktop version, or it can be installed as a plugin within an LMS (WIRIS, 2016). Both the desktop and LMS version requires the latest version of JAVA as well as an updated web browser. WIRIS is supported by all web browsers (Google Chrome, Firefox, Internet Explorer, Safari, etc.) as well as all other available platforms such as android, apple and windows devices.

6.21.3.5 Hardware requirements

The minimum hard drive space required to install and run Moodle is between 160 megabytes (160 MB) to five gigabytes (5GB) (Moodle, 2016). Where one megabyte is equal to 1024 kilobytes of data and one gigabyte is equal to 1,024 megabytes. For example, a one-gigabyte hard drive can hold approximately 240 songs, depending on the format of the songs. Also, a 512-kilobyte drive can hold approximately 350 photos or 102 songs or more or less one hour of a TV episode. Furthermore, to smoothly install and run Moodle you need at least one gigabyte of

random access memory (RAM). RAM is a computer type memory that can be accessed randomly.

The current version of Moodle was installed on a web server, and it is located at <http://myleerhoekie.co.za>. All the requirements to install and run Moodle, GeoGebra, and WIRIS, was met i.e. software requirements, hardware prerequisites, and additional plugins. Although all of the above seems time-consuming and requires a lot of technical know-how, choosing an effective web hosting company can handle all of the above. In other words, the web hosting company provides the space, the required software, and memory. This option was chosen to set up the current website.

All other standard requirements to run Moodle are captured within table 6.16 below.

Requirements	Available at school
Network infrastructure	ADSL line with internet speed up to four MB.
Desktop Computers	Core I 3, 4 GIG Ram, 500 GIG HDD
Web browsers	Google Chrome version 30
JAVA	Version 8.0
Adobe Flash Player	Version 21.0.0.182

Table 6.16: Other requirements to run Moodle.

As seen from the above table, '*school dee*' (a pseudonym used) meets all the requirements to install and run Moodle, WIRIS, and GeoGebra. All the required software was installed.

However, from the data extracted from the interviews and field notes, it became visible WIRIS runs better while utilizing Internet Explorer. For this reason, Internet Explorer was used as the default web browser.

Also, continual updates of JAVA became available during the research project. On the contrary, an outdated JAVA version resulted in WIRIS and GeoGebra not displaying correctly. Therefore, the teacher had to make sure that JAVA was up to date and that it was properly installed in Moodle.

Another issue that needed attention was the bandwidth, i.e. internet speed. Since data from the data collection techniques indicated that the internet speed was intermittent, a request was sent to the principle to upgrade our current ADSL line. The principle adhered to this request, and problems with the internet access were solved. However, another solution that was installing the LMS on the server in the mathematics lab. In other words, no internet connection was needed, and all the computers in the mathematics lab could access the LMS on the network. Not only did this increase the loading speed of the website, but it also eliminated bandwidth problems experienced by the school.

The issue with load shedding was also solved by purchasing uninterrupted power supplies which gave us enough time to save our work when we knew load shedding would occur.

The question that should be asked is: *what are the implications for teachers and Deaf and H/H learners?* This issue will be dealt with by looking at each entity individually.

6.21.4 Implications for teachers

When we zoom in on the above technical jargon and prerequisites of OMA, it becomes apparent that teachers need to be prepared in advance to integrate this type of technology into their classrooms. Not only will this require teachers to have sound content knowledge but also excellent pedagogical knowledge and technological expertise (Koehler & Mishra, 2009). Therefore, teachers who want to utilize technology in the teaching and learning process need to understand what, how and at which point to integrate technology into their subject matter.

Koehler and Mishra (2009) proposed a set of knowledge and skills for teachers who want to integrate technology into their teaching and learning. They defined this set of knowledge as the Technology, Pedagogy and Content Knowledge (TPACK) framework to guide teachers who want to teach with and about technology. “TPACK provides a dynamic framework for viewing teachers’ knowledge necessary for the design of curriculum and instruction focused on the preparation of their students for thinking and learning mathematics with digital technologies” (Koehler & Mishra, 2009:7).

TPACK originated from Shulman’s (1986) Pedagogical Content Knowledge (PCK). The TPACK model consists of three components of teacher knowledge i.e. Content, Pedagogy, and

Technology. More importantly are the interactions between these principal components which exemplify Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK) and Technological Pedagogical Content Knowledge (TPACK).

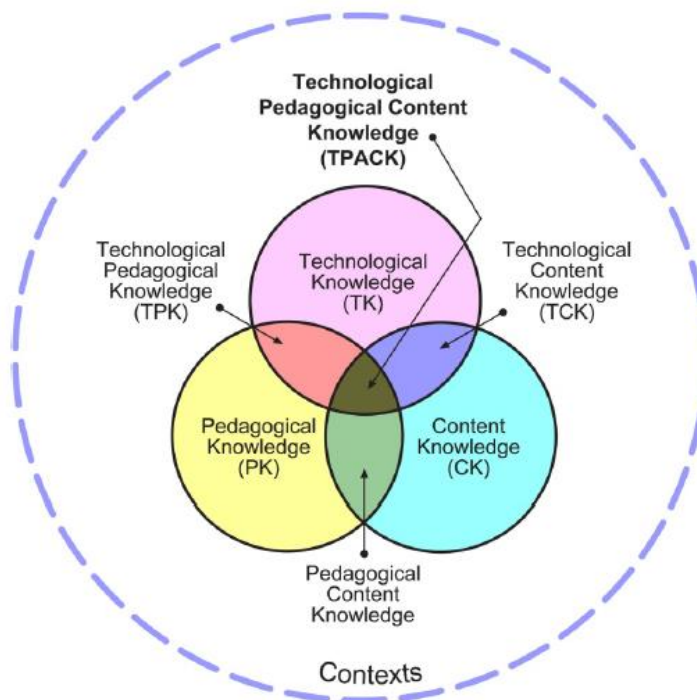


Figure 6.42: The TPACK model representing the body of knowledge required by teachers to integrate technology into their subject matter [Adopted: Koehler & Mishra, 2007:63]

Each of these components will now be discussed briefly.

6.21.4.1 Content Knowledge

Content knowledge refers to the teacher's knowledge base about his/her specific subject content which underpins the education process. Although Shulman (1986) claims that the subject content should include theories, ideas, and concepts my view is that it should also include a deeper level of understanding of the subject content. For example, teaching Pythagoras theorem might include the history of the mathematician, Pythagoras, how ordinary people couldn't approach him, how he lived behind glass walls, etc. In other words, creating more context to the

curriculum content. The absence of sound content knowledge can have devastating results such as learners obtaining misguided information from teachers and hence develop flaws in their understanding.

6.21.4.2 Pedagogical Knowledge

Pedagogical Knowledge focuses on the methods employed by the teacher within the teaching and learning process. Teachers with sound pedagogical knowledge are knowledgeable in how their learners learn, how to manage their classrooms effectively, planning lessons and school-based assessment. In sum, Pedagogical Knowledge also presupposes that teachers are knowledgeable in the different learning theories and in which manner they can adapt their teaching and learning to accommodate each learners' needs.

6.21.4.3 Pedagogical Content Knowledge

Pedagogical Content Knowledge refers to the process whereby teachers translate subject content, present it to students in a creative manner, implement intervention strategies for those that struggle with the subject matter as well as modifying the content to align it with each student's individual learning preferences and needs. Accordingly, PCK centers around the teaching, learning, assessment and feedback of the subject matter. It also includes continual reflection on your praxis to not only adjust your teaching strategies but to acknowledge flaws in your approach and misconceptions within learners.

6.21.4.4 Technology Knowledge

According to Koehler & Mishra (2007) Technology Knowledge, within the TPACK model, refers to a “deeper, more essential understanding and mastery of information technology for information processing, communication and problem solving” (p.64). Essentially it means that an individual with TK can use information technology in an array of ways to accomplish tasks more effortless and efficiently.

6.21.4.5 Technological Content Knowledge

TCK refers to the grasping of how technology and subject matter can impinge or improve one another. Essentially this means that teacher should understand in what way the content they teach can be modified when integrating it with technology. As a result, teachers should also be aware of what type of technologies are suited for particular content and what aren't.

6.21.4.6 Technological Pedagogical Knowledge

TPK encompass the realization of the “pedagogical affordances and constraints” about the different technological tools within a variety of contexts (Koehler & Mishra, 2007:65). Therefore, teachers have to look beyond the default functions of technology and adopt a creative ‘out of the box’ stance towards applying technology as a teaching and learning tool.

6.21.4.7 Technology, Pedagogy and Content Knowledge

TPACK relates to a rigorous understanding which surfaces from the interconnectedness of content, pedagogy and technology knowledge. To put it succinctly, TPACK is “the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students’ prior knowledge and theories of epistemology and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones” (Koehler & Mishra, 2007:66). For example, flipped classrooms have forced teachers to modify the teaching strategies to represent content successfully online. Teachers also had to reevaluate how learners can gain access to online learning and how collaboration between students can take place in an online learning environment. TPACK focuses on the integration of content, pedagogy, and technology and therefore teachers should have a thorough understanding of all three, separately as well as integrated within the education process.

From the above, it becomes apparent that teachers need a lot of development in the form of in-service training and workshops to integrate technology in their respective classroom. Since technology is constantly changing, these courses should occur on a regular basis. Also, universities and colleges should modify its courses to integrate the use of technology as a pedagogical tool in the classroom to prepare young teachers in the effective use of technology in the subject matter. In other words, a compulsory module should be added to the university course curriculum that addresses this issue. More importantly, teachers should not be expected to teach a subject they are not trained in and therefore first need to interpret the content before it can be taught to learners.

6.21.5 Implications for Deaf and H/H learners

While busy analyzing the answers users provided during the interview sessions as well as reading through their journal entries, especially those in Plan 1, the obvious response was: “too hard, too complicated.” A deeper analysis of these answers pointed to a somewhat distressful conclusion. These users were on the brink of giving up or quitting when presented with problems either with the OMA or the eLearning environment. To counter this issue, Lynch (2001) proposed an online orientation course to prepare learners for difficulties they might experience with online courses. The rationale behind such an orientation program would be to familiarize students with all the elements and tools they will use during their online experience.

On the other hand, Bozarth, Chapman, and LaMonica (2004) argue that an orientation course should also include elements such as:

- The expectations of teachers and learners;
- Directions in online etiquette;
- Visibility of online support structures;
- A pre-assessment of how prepared students are for online learning;

Sun, Tsai, Finger, Chen and Yeh (2008) argue that when learning with technology (eLearning) issues such as the learners’ behavior towards computers should gain attention. They are of the view that a positive behavior towards computers can lead to a positive learning experience with technology. Also, teachers should give attention to those learners that have some form of

computer anxiety. They also assert that self-efficacy in technology use will strongly influence their ability to use the technology for learning.

From my experience, I believe that learners should accumulate expertise in the use of technology for learning. The more familiar they become with the use of technology, the more motivated they become in using the technology for learning.

In summary, learners also need regular refreshing courses to guide them through the use of technology in the classroom. Whether it's the internet, VLEs, calculators, CAS's, etc., they need to be updated with new trends of utilizing these type of technologies and others in their learning and problem solving processes.

6.22 Summary

Looking at the discoveries above it becomes apparent that integrating technology in your classroom is not a straight forward process. A lot of planning needs to be done in advance before online teaching and learning can commence. Not only are there technological prerequisites that need to be addressed but the users also need to be trained and prepared for such a move.

However, weighing the potential benefits that can be gained from integrating technology into the teaching and learning process, training and development is a small price to pay.

In line with the above, the Western Cape Education Department has rolled out an ICT integration training in the Western Cape as part of the professional development for teachers. These training courses were conducted since 2007 and are still in progress. It includes courses such as Microsoft Partners in Learning (MSPiL), Moodle basics, Webquest, Intel Teach Essentials, E-Content development and is busy implementing the E-Pedagogy course. Although there is still a long way to go, teachers are becoming more and more aware of the advantages ICT can bring to the teaching and learning process.

Ample opportunities are provided for teachers to become skilled in technology integration in the classroom. It is thus up to them to take the first step in obtaining the skills to use technology efficiently and effectively

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This section of the paper focuses on a summary of the research project and a description of the findings of this study. Secondly, it includes the limitations of the current study as well as recommendations for future research.

7.2 Summary of the research project

The current research study's aim was to answer the following research question: *How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners?*

The analysis and discussion section above illuminate useful results of this research study. Based on the results of the users while interacting with the OMA, it can be noted that Deaf and H/H learners experience difficulties when presented with written text. Although this argument is well emphasized in different research studies such as Kelly, Lang and Pagliaro (2003); Pagliaro and Ansell (2002) and Pagliaro (2006); Barham and Bishop (1991); Kelly and Mousely (1999); Kidd and Lamb (1993); Kidd, Madsen, and Lamb (1993) it is further corroborated by this research study. Also, a useful discovery based on the obstacles written text presents is the fact that providing definitions of written text using Sign Language aren't the solution alone. Although it is helpful to broaden Deaf and H/H learners' vocabulary, the concept that teachers want them to understand needs to be translated via Sign Language. For instance, one of the modifications implemented during Plan two was to link unfamiliar words to a glossary. Hence, users could click on a name, and a popup will appear giving a definition of the concept in Sign Language. For some users (20%) this was helpful, other (80%) users needed a translation of the concept to understand the question.

A second finding that proved useful during the analysis of the data collection techniques was the dependency of Deaf and H/H learners on multi-representations of mathematics content for understanding school mathematics. This view is in line with Blatto-Vallee, Kelly, Gaustad, Porter, and Fonzi's (2007) argument that Deaf and H/H learners' test scores usually increase when the

visual-spatial schematic representations of the mathematics problems increased. Although the findings of this research study agree with this view, a further discovery indicates that multi-representation alone did not enhance their test scores but the mediation attributes of these multi-representations. In other words, by presenting Deaf and H/H learners with static imagery will not increase their understanding of mathematics concepts. However, when these multi-representations are interactive and can guide students in discovering the “hidden mathematics” i.e. knowledge construction, then it has the possibility of increasing their understanding and hence their test scores.

Another significant discovery within this research project was the usefulness of meaningful feedback. Researchers such as Butler, Pyzdrowski, Goodykoontz and Walker (2008) and Brothen, Daniel, Finley, and Force (2004) all agree on the usefulness of meaningful feedback. However, these views refer to feedback based on a breakdown of the solution to the problem. Although I agree with these views, I discovered that utilizing interactive videos as a means of feedback have greater value than just a breakdown of the solution or the correct answer. The interactive video becomes a learning tool in itself and can further enhance learners’ understanding of mathematics concepts, in this case, the function concept.

A further meaningful discovery was the value of a computer mediated learning environment. Moodle was setup to act as a mediator between learners, the content and the teacher. As a result, it was found that the pupils’ understanding of the function concept increased as the mediation increased. This discovery is also in line with Graham and Misanchuk (2005); Uribe, Klein, and Sullivan (2003), Ping and Swe’s (2004) view that a computer mediated learning environment has the potential to increase learners’ overall performance. Also, an important discovery was the role students played in the mediation process. Those with a sound understanding of the function concept could guide other learners and assist them in their understanding.

Journaling was found extremely useful, and a means to reflect on the learning process of each participant. This discovery was in line with Urquhart (2009) view that writing in the mathematics class can improve the performance of students. Although Deaf and H/H learners experience difficulty in expressing themselves, they could be guided by effective questioning. Also, problems they experienced while interacting with the OMA surfaced through their journal entries.

Accordingly, the teacher became aware of these problems and could modify the OMA in line with their individual needs.

The most obvious discovery was the major role Sign Language played in the Deaf and H/H learners' teaching and learning. Deaf and H/H students can't learn without incorporating Sign Language in their education process. Furthermore, since signs for concepts in mathematics are none existent, it makes it tough to translate these ideas via Sign Language without losing the essence of the math concept. The above argument was also a concern for Ansell and Pagliaro (2001) who posit that when teachers use Sign Language to convey mathematics question, they must use the correct mathematical terms which should not create confusion amongst Deaf learners. A work around this obstacle was providing participants with video examples for them to experience the mathematics concept that needs to be conveyed and then guiding them through questioning. For this reason, each question within the OMA included an icon which they could click on which presented them with a video example. These 'help' features were extremely useful especially with the limited Sign Language concept vocabulary at hand.

More importantly, it was discovered that teachers who want to utilize OMA as an alternate assessment should acquire training in the different facets of technology, pedagogy, and content. The problems learners experienced especially with Moodle, WIRIS and all the prerequisites of the OMA, presupposes that teachers should have the ability and skills to assist them in these problem areas. Therefore, teachers should obtain professional development in these sectors to utilize and integrate technology into their respective classrooms effectively.

One crucial finding that altered my perspective on creating complex test questions, specifically quiz items for online assessment, was the use of the CR matrix. My view on creating assessment questions was that the more difficult the questions are, the more in depth I'm testing learners' understanding of the concept, however, this isn't the case. A combination of the revised Bloom's taxonomy and the DOK levels i.e. CR matrix has the potential to align subject matter and assessment item development. In other words, not only does the CR embrace the complexity of the content but the cognitive demand learners need to possess to answer these type of assessment questions and therefore heighten classroom evaluation and also increase the learning prospects of Deaf and H/H students.

Therefore, in answering the research question: How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners? This research study can conclude that for OMA to encourage the development of cognitive functions in Deaf and H/H students it should adhere to the following:

- Should be dominated by Sign Language;
- Must include interactive and challenging test items;
- Should encompass the broad spectrum of the CR matrix;
- Should be able to act as a mediation tool;
- Provide opportunities for learners to construct their knowledge;
- Dynamic multi-representation features must support test items;
- It must provide opportunities for learners to self-reflect and adjust their views;

7.3 Limitations of this study

The first limitation of this research study was the sample size. It only included eight Grade 8 Deaf and H/H learners. Also, these learners were from one school in the Western Cape which further highlights the limitation. However, the small sample size allowed for an in-depth study of students' specific learning needs and the OMA could be adjusted accordingly. Secondly, only one assessment type was investigated. The quiz module, which is one of many assignment modules were the focus of this research study which also presents a limitation. Furthermore, this research study only focused on one content area i.e. Functions and relationships. Therefore, the findings cannot be generalized to other content areas in mathematics.

7.4 Possible recommendations for future research

One possible proposal for a future study would include all the testing modules in Moodle. Hence, investigating the effectiveness of each assignment module and how each one can promote the cognitive functions of Deaf and H/H learners. Also, teachers' readiness to integrate technology in the mathematics class looking specifically at the TPACK model. Moreover, research should

include OMA based on all the content areas in mathematics to investigate whether it is possible to use it as an alternate assessment for Deaf and H/H learners. Also, research needs to be conducted in the use of online journaling in the mathematics classroom specifically for Deaf students while making use of other plugins where learners can sign their journal entries.

My conclusion then is that OMA as an alternate assessment has the potential to promote the cognitive functions of Deaf and H/H Grade 8 learners. Although an array of potential pitfalls surfaced within this research study, constructing the OMA based on critical characteristics could limit these potential pitfalls and mediate these students' learning processes.

Addendum A (Research approval from the Research Ethics Committee, US)



UNIVERSITEIT • STELLENBOSCH • UNIVERSITY
jou kennisvenoot • your knowledge partner

Approval Notice Response to Modifications- (New Application)

09-Sep-2015
Damon, Nolan NB

Proposal #: HS1197/2015

Title: The viability of online mathematics assessment as an alternate assessment for deaf and hard of hearing learners in the senior phase.

Dear Mr Nolan Damon,

Your **Response to Modifications - (New Application)** received on **20-Aug-2015**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **08-Sep-2015** and was approved.
Please note the following information about your approved research proposal:

Proposal Approval Period: **08-Sep-2015 -07-Sep-2016**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number (HS1197/2015)** on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Included Documents:

Permission letter_WCED

Research Proposal

Assent form_AFR

Informed consent form_parent

REVISED_Interview schedule_AFR

REVISED_REC application form

Interview schedule_ENG

REVISED_Assent form_AFR

REVISED_Response to Modifications

REC Application form

Interview schedule_AFR
Permission letter_School
REVISED_Permission letter_School
DESC Checklist form
REVISED_Permission letter_WCED
REVISED_Informed consent form
REVISED_Research proposal
REVISED_DESC Checklist form

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Addendum B (Research approval letter from WCED)



Directorate: Research

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20150527-48603

ENQUIRIES: Dr A T Wyngaard

Mr Nolan Damon
4 Hennie Ferrus Crescent
Parkersdam
Worcester
6850

Dear Mr Nolan Damon

RESEARCH PROPOSAL: THE INTRODUCTION OF ONLINE MATHEMATICS ASSESSMENT AS AN ALTERNATE ASSESSMENT TO FACILITATE MATHEMATICS LEARNING OF GRADE 8 DEAF AND HARD OF HEARING LEARNERS

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **20 July 2015 till 30 September 2015**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard


Directorate: Research

DATE: 28 May 2015

Lower Parliament Street, Cape Town, 8001
tel: +27 21 467 9272 fax: 0865902282
Safe Schools: 0800 45 46 47

Private Bag X9114, Cape Town, 8000
Employment and salary enquiries: 0861 92 33 22
www.westerncape.gov.za

Addendum C (Research approval letter from the SGB, Nuwe Hoop Centre)



NUWE HOOP-SENTRUM VIR GEHOORGESTREMDES
Privaatsak X3047 / Private Bag X3047
Worcester 6849
E-pos / E-mail: admin@nuwehoop.wcape.school.za
Webtuiste / Website: www.worcesterdeaf.co.za
Telefoon / Telephone: 023 348 2200 / 023 346 5000
Faks / Fax: 023 348 2235

NUWE HOOP CENTRE FOR THE HEARING IMPAIRED
Gestig - 1933 - Founded

27 Februarie 2015

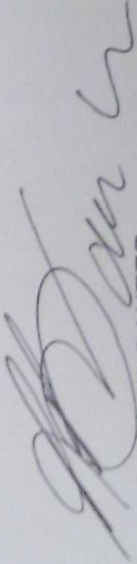
Mnr. Nolan Damon

i.s NAVORSING VIR NAGRAADSE STUDIE

Hiermee stel ons u in kennis dat die beheerliggaam u aansoek hanteer het.

Dit is vir ons 'n besonderse voorreg om toestemming aan u te verleen om voort te gaan met u navorsing by ons skool. Ons wens u alle sterkte toe met u studies en vertrou dat die uitkoms 'n positiewe invloed op uself, u gesin, die gemeenskap en die opvoedingsproses in geheel sal hê.

Nuwe Hoop groete



ROLAND BAXTER
SEKRETARIS

Addendum D (Consent to participate in the research study, US)



UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY CONSENT TO PARTICIPATE IN RESEARCH

The introduction of online mathematics assessment as an alternate assessment to facilitate mathematics learning of Grade 8 Deaf and Hard of Hearing learners.

Your son/daughter is invited to participate in a research study conducted by Nolan Damon, PhD Degree, from the Curriculum Studies Department at Stellenbosch University. He/she was selected as a possible participant in this study because the study revolves around Deaf and hard of hearing learners' struggle with mathematics assessment and how the online mathematics assessment might assist him/her in his/her struggle. Since your son/daughter is deaf/hard of hearing and struggle with mathematics assessments, he/she is eligible to participate in this study.

1. PURPOSE OF THE STUDY

The aim of this study is to create online mathematics assessment as an alternate assessment with respect to Grade 8 Deaf and Hard of Hearing learners, to determine:

How can the use of online mathematics assessment as an alternate assessment promote the development of cognitive functions in Deaf and H/H Grade 8 learners?

2. PROCEDURES

If you grant permission to your son/daughter to participate in this study, we would ask him/her to do the following things:

Your son/daughter will be asked to interact with online mathematics assessments by following the stages below.

Stage 1

Firstly, your son/daughter will be asked to participate in an online learning environment by interacting with mathematics assessment. These online mathematics assessment are part of the Grade 8 mathematics curriculum set out in CAPS. Your son's /daughter's interaction within these online mathematics assessment will be recorded and closely monitored by me.. The knowledge acquired from his/her first interaction will form his/her baseline knowledge of the content. The results of your son's /daughter's interaction in these mathematics assessment will be recorded and used to adjust the mathematics assessment according to his/her individual needs. An interview will be conducted individually and in groups for further recommendations and comments

Stage 2

In the second stage your son/daughter will be asked to participate in the adjusted online mathematics assessment. Here the results will be analyzed to see whether the adjusted online mathematics assessment had any effect on your son's/daughter's performance in mathematics. The second stage will last approximately 3 weeks in which he/she will interact with the adjusted mathematics assessment.

Both stages will take place at Nuwe Hoop Centre, in the Computer Lab, room C.012. The project will run from the 25th of July 2015 up until the 19th of September 2015. The classes will also be administered outside of the normal mathematics classes between the hours of 09h00 and 13h00 on Saturdays.

3. POTENTIAL RISKS AND DISCOMFORTS

The learning environment your son/daughter will engage in presents no foreseeable risk since it is safe and user-friendly. Since, I have been teaching computer practice to your son/daughter from Grade 7, he/she is familiar with the learning environment and how to keep him/her safe in front of the computer.

A potential discomfort might be that your son/daughter isn't too comfortable in front of the computer. This discomfort will be rectified through continual exposure to the computers by means of educational games. Learners, especially the deaf learners, loves games and this will be used not only to familiarize your son/daughter with computers as a learning tool but also to remove any anxiety he/she might experience when working with computers.

Furthermore, there are no significant physical or psychological risks to participating in the study which will result in the researcher terminating the study. What this mean is that in no way will your son/daughter be mistreated or his/her rights be violated, since this will result in a failed research project. In addition to ensure that there is no inconvenience to your son/daughter, the study will not be conducted within the normal mathematics classes.

Moreover, the online mathematics assessments are designed in line with the Curriculum and Assessment Policy Guidelines (CAPS) specific to the Grade 8 mathematics curriculum which is specified by the Department of Education.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The potential benefits of this research study to school mathematics for deaf learners will be of great value. Not only may it highlight why deaf learners struggle with written mathematics assessments, but it might also show how the barriers deaf learners experience in written mathematics assessments can possible be minimized through the use of online mathematics assessment as an alternate assessment.

Furthermore, the research might point out what online mathematics assessment should look like in order for it to complement and enrich the school mathematics curriculum for the deaf learners.

In addition the research will highlight the measurement and operational implications of using online mathematics assessment as an alternate assessment. Moreover, the study might also have possible benefits for the deaf /hard of hearing community since improvements in the

performance of Deaf learners in school mathematics might guarantee them access to higher education and possible career advancements.

5. PAYMENT FOR PARTICIPATION

No payments will be given to any of the subjects. The study will be conducted with your son/daughter out of his/her own free will.

6. CONFIDENTIALITY

Any information that will be obtained in connection with this study and that can be identified with your son/daughter will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of: Coding procedures and safeguarding of data.

- **Coding Procedure**

The ethical integrity of this study will be maintained by conducting the study under the auspices of the ethics committee of the University of Stellenbosch. Moreover, the privacy, anonymity and confidentiality of your sons'/daughters' records will be secured in my research report by replacing their real identities with pseudonyms. The researcher will thus code the data using the pseudonyms especially in the case of publication. Furthermore, I will institute the maximum effort and exercise caution in order to protect the identity of your son/daughter. Your son/daughter will thus remain anonymous.

- **Plans to safeguard the data**

The biographical data as well as the transcribed interviews of your son/daughter will be kept safe on my personal computer's hard drive. No one except me have access to my personal computer which is password protected.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether your son/daughter should participate in this study or not. If you provide consent for your son/daughter to participate in this study, he/she may withdraw at any time without consequences of any kind. He/she may also refuse to answer any questions he/she does not want to answer and still remain in the study. The investigator may withdraw him/her from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact the following research personnel:

Principal Investigator:

Name: Nolan Damon

Contact Information: Home: 0233474372

Cellphone: 0711789322

Address:

4 Hennie Ferruscrescent

Parkersdam
Worcester
6850

Supervisor

Name: Faaiz Gierdien

Contact Information: tel: 27 21 808 2289 (O)
fax: 27 21 808 2295

Address: Dept of Curriculum Studies
Faculty of Education
Stellenbosch University
Private Bag X1
Matieland
7602
South Africa

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue your sons'/daughters' participation without penalty. Your son/daughter are not waiving any legal claims, rights or remedies because of his/her participation in this research study. If you have questions regarding his/her rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to [*me/the subject/the participant*] by Mr. N Damon in Sign Language and [*I am/the subject is/the participant is*] in command of this language or it was satisfactorily translated to [*me/him/her*]. [*I/the participant/the subject*] were given the opportunity to ask questions and these questions were answered to [*my/his/her*] satisfaction.

[*I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study.*] I have been given a copy of this form.

Name of Subject/Participant

Name of Legal Representative (if applicable)

Signature of Subject/Participant or Legal Representative

Date

SIGNATURE OF INVESTIGATOR

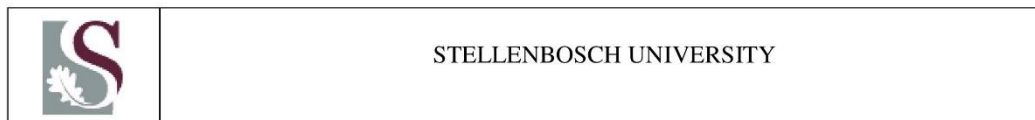
I declare that I explained the information given in this document to _____ [*name of the subject/participant*] and/or [his/her] representative _____ [*name of the representative*]. [*He/she*] was encouraged and given ample time to ask me any questions. This

conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into Sign Language*] by Nolan Damon.

Signature of Investigator

Date

Addendum E (Participation information leaflet and assent form)



DEELNAME INFORMASIE PAMFLET EN TOESTEMMINGSVORM



TITEL VAN DIE NAVORSINGSPROJEK: Die bekendstelling van internet-gebaseerde assessering as 'n alternatiewe assessering vir Dowe en Hardhorende Graad 8 leerders

NAVORSER SE NAAM: Nolan Damon

ADRES: 4 Hennie Ferrussingel, Parkersdam, Worcester, 6850

KONTAK NOMMER: 0711789322

Wat is NAVORSING?

Navorsing is iets wat ons doen om nuwe inligting te vin deur hoe dinge(en mense) werk. Ons gebruik navorsingsprojekte of studies om meer te leer oor siektes. Navorsing help ons ook om beter maniere te vind om siek kinders te help of te behandel.

Waaroor handel hierdie navorsingsprojek?

Hierdie navorsingsprojek handel oor die moontlikheid van internet-gebaseerde assessering as 'n alternatiewe assessering vir Dowe en Hardhorende leerders. Omdat Dowe en Hardhorende leerders sukkel met wiskunde assesseringstake, het ek dit goed gedink om 'n manier te ondersoek om Dowe en Hardhorende leerders te help sodat hulle wiskunde assesseringstake beter kan verstaan.

Hoekom is ek uitgenooi om aan hierdie navorsingsprojek deel te neem?

Die doel van hierdie navorsingsprojek is om Dowe en Hardhorende leerders by Nuwe Hoop Sentrum te help met moeilikhede wat hulle ondervind tydens Wiskunde assesseringstake. Jy, , besit dus al die eienskappe wat 'n deelnemer nodig het om aan hierdie navorsingsprojek deel te neem.

Wie doen hierdie navorsing?

Ek is Mnr. Nolan Damon. Ek is 'n onderwyser by Nuwe Hoop Sentrum, 'n skool vir Dowe en Hardhorende leerders. Ek onderrig wiskunde en rekenaarvaardighede. Ek het die afgelope 11 jaar ervaar dat Dowe en Hardhorende leerders dit geweldig moeilik vind om wiskunde assesseringstake. Hulle sukkel gedurig om vrae in wiskunde vraestelle te verstaan en kry dit die meeste van die gevalle die antwoorde verkeerd. Dit is hoekom ek dit belangrik gesien het

om die navorsingsprojek te doen om uit te vind hoe internet-gebaseerde assessering as 'n alternatiewe assessering vir Dowe en Hardhorende leerders Dowe en Hardhorende leerders kan help met moeilikhede wat hulle ondervind met wiskunde assessering..

Wat sal met my gebeur in hierdie studie?

Van jou word verwag om die internet-gebaseerde vraestel wat deur die onderwyser opgestel is, te doen. Die vraestel is gebaseer op die wiskunde kurrikulum. Hierdie vraestel is ontwikkel in WIRIS en Moodle wat 'n eLeer omgewing is. WIRIS sal jou help om wiskunde konsepte beter te verstaan en die video en interaktiewe oefeninge wat in die aanlyn vraestel vervat is, sal jou help om die vrae beter te verstaan. Daar is deurgaans hulp d.m.v prente, gebare en visuele voorstellings.

Kan enige iets negatiefs met my gebeur?

Daar is geen risiko's aan verbonde in hierdie projek nie en kan net tot jou voordeel wees.

Kan enige iets goed met my gebeur?

Wat kan plaasvind is dat jy met behulp van WIRIS en Moodle asook die visuele voorstellings, wiskunde assessering beter sal kan verstaan en ten einde beter resultate sal kry in hierdie tipe assessering. Deur gebruik te maak van WIRIS gaan jy gelei word om self ook vrae te skep deur verskillende oplossingsmetodes te gebruik.

Sal enige iemand weet dat ek in die studie is?

Jou persoonlike inligting sal ten alle tye op 'n vertroulike manier hanteer word. Die uitslag van die navorsingsprojek gaan aan die einde van die projek aan die skool bekend gemaak word. Jou vertroulikheid sal onder geen omstandighede geskend word nie. Slegs die inligting rakende die uitslag van die projek gaan gepubliseer word om sodoende die geldigheid van die projek uit te lig.



Met wie kan ek praat oor die studie?

Jy kan ter enige tyd my, Mnr. Damon, kontak by 0711789322 of selfs by 0233474372. Indien jy nie met my wil praat nie, kan jy ter enige tyd met Mnr. Erasmus, die skoolhoof praat. Sy telefoonnommer is: 0233482200. Jy kan ook Mnr.Humphreys kontak by 0233482200.

Wat as ek nie aan die navorsingsprojek wil deel neem nie?

Jy kan nie in die moeilikheid kom deur te weier om aan die navorsingsprojek deel te neem nie. Indien jy wel deel neem aan die navorsingsprojek, kan jy ter enige tyd onttrek uit die projek uit. Jy sal dus nie verplig word of gedwing word om verder aan die projek deel te neem nie.

Verstaan jy hierdie navorsingsstudie en is jy bereid om daarin deel te neem?

JA

NEE

Het die navorser al jou vrae beantwoord?

JA

NEE

Verstaan jy dat jy ter enige tyd van die studie kan onttrek?

JA

NEE

Hantekening van kind

Datum

References

- Alant, E., and Casey, M. 2005. Assessment concessions for learners with impairments. *South African journal of education*, 25(3):185-189.
- Anderson, T., 2008. *The theory and practice of online learning*. Athabasca University Press.
- Anderson, L.W., Krathwohl, D.R., and Bloom, B.S., 2001. *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Allyn & Bacon.
- Andrews, J.F., Leigh, I., and Weiner, M.T., 2004. *Deaf people: Evolving perspectives from psychology, education, and sociology*. Pearson College Division.
- Almond P. J., and Case B. J., 2004. Alternate Assessments for Students with Significant Cognitive Disabilities. [Online]. Available: http://images.pearsonassessments.com/images/tmrs/tmrs_rg/AlternateAssessments.pdf?WT.mc_id=TMRS_Alternate_Assessments_for_Students. [February 1, 2015].
- Alves, G. R., Viegas, C., Marques, M. A., Costa-Lobo, C., Silva, A. A., Formanski, F., and Silva, J. B. D. 2013. Impact of different Moodle course designs on students' Performance. [Online]. Available: http://recipp.ipp.pt/bitstream/10400.22/4371/1/ART_GustavoAlves_2013_CIETI.pdf [October 4, 2015].
- Ansell, E., and Pagliaro, C. M. 2001. Effects of a signed translation on the type and difficulty of arithmetic story problems. *Focus on Learning Problems in Mathematics*, 23(2–3):41–69.
- Babbie, E., 2007. *The Practice of Social Research*. Cengage Learning.
- Babbie, E., 2010. *The Practice of Social Research*. Cengage Learning.
- Babbie, E., 2015. *The Practice of Social Research*. Cengage Learning.
- Babbitt, B. and Miller, S. 1996. Using hypermedia to improve the mathematics problem-solving skills of students with disabilities. *Journal of Learning Disabilities*, 29, 4, 391–401.
- Baird, J.R., Fensham, P.J., Gunstone, R.F., and White, R.T., 1991. The importance of reflection in improving science teaching and learning. *Journal of research in Science Teaching*, 28(2), pp.163-182.

- Balcazar, F. E., Keys, C. B., Kaplan, D. L., and Suarez-Balcazar, Y., 1998. Participatory action research and people with disabilities: Principles and challenges. *Canadian Journal of Rehabilitation*, 12, 105-112.
- Barham, J., and Bishop, A. 1991. Mathematics and the deaf child. In K. Durkin and B. Shire (eds.), *Language in mathematical education: Research and practice*. Philadelphia: Open University Press.
- Baum, F., MacDougall, C., and Smith, D. 2006. Participatory action research. *Journal of epidemiology and community health*, 60(10):854.
- Berent, G.P., and Kelly, R.R., 2008. The Efficacy of Visual Input Enhancement in Teaching Deaf Learners of L2 English. *Understanding second language process*, 25, p.80.
- Berg, F.S., and Fletcher, S.G., 1970. *The Hard of Hearing Child: Clinical and Educational Management*.
- Berger, P.L., and Luckmann, T., 1991. *The social construction of reality: A treatise in the sociology of knowledge* (No. 10). Penguin UK.
- Biehler, R., 1994. *Didactics of mathematics as a scientific discipline* (Vol. 13). Springer Science and Business Media.
- Bielinski, J., Thurlow, M., Ysseldyke, J., Freidebach, J., and Freidebach, M. 2001. *Read-aloud accommodations: Effects on multiple-choice reading and math items* (TechnicalReport 31). Minneapolis, MN: The University of Minnesota, National Center on Educational Outcomes. [Online]. Available: <http://education.umn.edu/NCEO/OnlinePubs/Technical31.htm>. [May 30, 2015].
- Biggam, J. 2008. *Succeeding with your Master's Dissertation: A step-by-step handbook*. Basingstoke: Palgrave.
- Bishop, A., 1985. The social construction of meaning: A significant development for mathematics education. *For the Learning of Mathematics*, 5(1), pp.24-28.
- Blake, B., and Pope, T. 2008. Developmental Psychology: Incorporating Piaget's and Vygotsky's Theories in Classrooms. *Journal of Cross-Disciplinary Perspectives in Education* 1(1), May 2008: 59 – 67. [Online]. Available: <http://jcpe.wmwikis.net/file/view/blakepope.pdf/330666844/blakepope.pdf> [2014, July 12].

- Blanco Abellán, M., Estela Carbonell, M. R., Ginovart Gisbert, M., and Saà Seoane, J. 2009. Computer assisted assessment through moodle quizzes for calculus in an engineering undergraduate course. *CIEAEM61*.
- Blatto-Vallee, G., Kelly, R. R., Gaustad, M. G., Porter, J., and Fonzi, J. 2007. Visual-spatial representation in mathematical problem-solving by deaf and hearing students. *Journal of Deaf Studies and Deaf Education*, 12(4):432-448.
- Bloom, B.S., 1956. Taxonomy of educational objectives. Vol. 1: Cognitive domain. *New York: McKay*, pp.20-24.
- Bogarrra Rodriguez, S., Corbalan Fuertes, M., Font Piera, A., Plaza Garcia, I., and Solsona, F. J. A. 2012. Lessons Learned in the Use of WIRIS Quizzes to Upgrade Moodle to Solve Electrical Circuits. *Education, IEEE Transactions on*, 55(3):412-417.
- Bottge, B., and Rueda, E. 2006. Low achievers may benefit from interactive mathematics. [Online] Available: http://www.wcer.wisc.edu/news/coverStories/low_achievers_may_benefit_from_interactive_math.php. [February 3, 2015].
- Bozarth, J., Chapman, D.D., and LaMonica, L., 2004. Preparing for Distance Learning: Designing an Online Student Orientation Course. *Educational Technology & Society*, 7(1), pp.87-106.
- Brown, P.J. 1999. Findings of the 1999 plain language field test. University of Delaware, Newark, DE: Delaware Research and Development Center.
- Brothen, T., Daniel, D. B., Finley, D. L., and Force, P. I. T. 2004. Best principles in the use of on-line quizzing. *Prepared for the Society for the Teaching of Psychology Pedagogical Innovations Task Force*. [Online]. Available: <http://teachpsych.org/Resources/Documents/otrp/pedagogy/onlinetesting.pdf> [October 11, 2015].
- Browder, D. M., Spooner, F., Algozzine, R., Ahlgrim-Delzell, L., Flowers, C., and Karvonen, M. 2003. What we know and need to know about alternate assessment. *Exceptional Children*, 70(1):45-61.
- Browder, D., Ahlgrim-Delzell, L., Flowers, C., Karvonen, M., Spooner, F., and Algozzine, R. 2005. How States Implement Alternate Assessments for Students with Disabilities Recommendations for National Policy. *Journal of Disability Policy Studies*, 15(4):209-220.

- Bull, R., Marschark, M., and Blatto-Vallee, G. 2005. SNARC hunting: Examining number representation in deaf students. *Learning and Individual Differences*, 15(3):223-236.
- Burch, M. A. 2002. Effects of computer-based test accommodations on the math problem-solving performance of students with and without disabilities. *Dissertation Abstracts International: Section A. Humanities and Social Sciences*, 63(3):902.
- Burton, S., and Steane, P. eds., 2004. *Surviving your thesis*. Routledge.
- Butcher, P. 2008. Online assessment at the Open University using open source software: Moodle, OpenMark and more.
- Butler, M., Pyzdrowski, L., Goodykoontz, A., and Walker, V., 2008. The Effects of Feedback on Online Quizzes. *International Journal of Technology in Mathematics Education*, 15(4):131-136.
- Calhoun, M. B., Fuchs, L. S., and Hamlett, C. L. 2000. Effects of computer-based test accommodations on mathematics performance assessments for secondary students with learning disabilities. *Learning Disability Quarterly*, 23(4):271–282.
- Calm, R., Ripoll, J., Masià, R., Sancho-Vinuesa, T., Olivé, C., Parés, N., and Pozo, F., 2012. Wiris Quizzes: An automatic and self-study tool for online mathematics: The teaching experience in engineering courses at Universitat Oberta de Catalunya. In *Computers in Education (SIIE)*, 2012 International Symposium on (pp. 1-6). IEEE.
- Case, B.J., 2005. Accommodations to improve Instruction and Assessment of Students Who Are Deaf or Hard of Hearing. Policy Report. Pearson. [Online]. Available: http://images.pearsonassessments.com/images/tmrs/tmrs_rg/Deaf.pdf?WT.mc_id=TMRS_Accommodations_for_the_Deaf. [March 21, 2015].
- Cates, JM. 2000. Making algebra accessible to all students: An important issue for all mathematics teachers. [Online] Available: [\[http://www.uscupstate.edu/uploadedFiles/academics/Education/makingalgebraaccessible.pdf\]](http://www.uscupstate.edu/uploadedFiles/academics/Education/makingalgebraaccessible.pdf) [25 March 2015].
- Cawthon SW, Online Research Lab. 2006. Findings from the National Survey on accommodations and alternate assessments for students who are deaf or hard of hearing. *Journal of Deaf Studies and Deaf Education* 11:337–359.

Cawthon, S. W. 2006. A national survey of accommodations and alternate assessments for students who are deaf or hard of hearing in the United States. *Journal of Deaf Studies and Deaf Education*, 11(3):337-359.

Cawthon, S. W. 2009. Making decisions about assessment practices for students who are deaf or hard of hearing. *Remedial and Special Education*.

Cawthon, S. W., and Wurtz, K. A. 2009. Alternate assessment uses with students who are deaf or hard of hearing: An exploratory mixed-methods analysis of portfolio, checklists, and out-of-level test formats. *Journal of deaf studies and deaf education*, 14(2):155-177.

Cawthon, S. W. 2010. Science and evidence of success: Two emerging issues in assessment accommodations for students who are deaf or hard of hearing. *Journal of deaf studies and deaf education*, 15(2):185-203.

Cawthon, S. 2011a. Making decisions about assessment practices for students who are deaf or hard of hearing. *Remedial and Special Education*, 32(1): 4–21.

Cawthon, S.W. 2011. Making a decision about assessment practices for students who are deaf or hard of hearing. *Remedial and Special Education*, 32(1):4-21.

Cawthon, S. W., Winton, S. M., Garberoglio, C. L., and Gobble, M. E. 2011. The effects of American Sign Language as an assessment accommodation for students who are deaf or hard of hearing. *Journal of Deaf Studies and Deaf Education*, 16(2):198–211.

Center for Universal Design. 1997. What is Universal Design? North Carolina State University. [Online]. Available: <http://universaldesign.ie/What-is-Universal-Design/The-7-Principles/> [January 12, 2016].

Chaiklin, S., 2003. The zone of proximal development in Vygotsky's analysis of learning and instruction. *Vygotsky's educational theory in cultural context*, 1, 39-64.

Chesler, M.A., 1991. Participatory action research with self-help groups: An alternative paradigm for inquiry and action. *American Journal of Community Psychology*, 19(5), pp.757-768.

Chien, T. C. 2008. Factors Influencing Computer Anxiety and Its Impact on E-Learning Effectiveness: A Review of Literature. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED501623.pdf>. [August 10, 2015].

- Circular: 0021/2009. Processes and Procedures for Exemptions and Concessions in Grade 9. [Online] Available: http://wced.school.za/circulars/circulars09/e21_09.html. [April 3, 2015].
- Cobb, P., Yackel, E., and Wood, T., 1992. A constructivist alternative to the representational view of mind in mathematics education. *Journal of Research in Mathematics education*, pp.2-33.
- Cole, J., and Foster, H., 2007. *Using Moodle: Teaching with the popular open source course management system*. "O'Reilly Media, Inc."
- Corbin, J. and Strauss, A., 2014. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications.
- Coy, J. 2013. *Instant Moodle Quiz Module How-To*. Creating Moodle quizzes to enhance learning using practical hands-on recipes. Pact Publishing. Birmingham. Mumbai.
- Crane, P., and O'Regan, M., 2010. *On PAR: Using participatory action research to improve early intervention*. Department of Families, Housing, Community Services and Indigenous Affairs, Australian Government.
- Creswell, J.W., 2014. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Damon, N. B., 2015. On the feasibility of Moodle use to assist Deaf and Hard of Hearing Grade 9 learners with mathematics problem-solving. Unpublished Master's Thesis. [Online]. Available: <http://scholar.sun.ac.za/handle/10019.1/96768>. [May 12, 2015].
- Davenport, J.H., Siret, Y. and Tournier, E., 1988. *Computer algebra* (Vol. 5). London: Academic Press.
- Davidson-Shivers, G.V., and Rasmussen, K.L., 2006. *Web-based Learning: Design, Implementation, and Evaluation*. Pearson. Merrill Prentice Hall. New Jersey.
- Davis, A., 1999. Educational Assessment: a critique of current policy. *Impact*, 1999(1), pp.vii-49.
- DeMarois, P., and Tall, D., 1996. Facets and layers of the function concept. In *PME CONFERENCE* (Vol. 2, pp. 2-297). THE PROGRAM COMMITTEE OF THE 18TH PME CONFERENCE.
- DeMarios, P., and Tall, D., 1999. Function: Organizing principle or cognitive root? In *PME CONFERENCE* (Vol. 2, pp. 2-257).

Denscombe, M., 2010. *The Good Research Guide: For small-scale social research projects*. 4th Edition. McGraw-Hill. Open University Press.

Denscombe, M. 2010. *Ground rules for social research: Guidelines for good practice*. McGraw-Hill Education (UK). Denzin, N.K., and Lincoln, Y.S. 2000. *Handbook of Qualitative Research*, 2nd Edition, Thousand Oaks, CA: Sage.

Denzin, N.K., and Lincoln, Y.S. 2005. *The Sage Handbook of Qualitative Research*. Sage Publications. California.

Denzin, N.K., and Lincoln, Y.S., 2008. *Collecting and interpreting qualitative materials* (Vol. 3). Sage.

Department of Education. Government Gazette 24 June 1998, volume 396 no. 18998. [Online]. Available: <http://www.polity.org.za/polity/govdocs/policy/assessment.html>. [January 3, 2016].

Department of Education. 2001. White Paper 6. Special Needs Education. Building an Inclusive Education and Training System. [Online]. Available: <http://www.education.gov.za/LinkClick.aspx?fileticket=gVFccZLi/tI=>. [March 10, 2012].

Department of Education. 2002. The draft guidelines for the implementation of inclusive education. Pretoria: Department of Education. [Online]. Available: <http://www.education.gov.za/LinkClick.aspx?fileticket=mBxVzYkx8fA%3D&tabid=452&dmid=1036>. [January 1, 2013].

Department of Education 2003a. National Curriculum Statement Grades 10 – 12 Mathematics (General). [Online]. Available: <http://www.education.gov.za/LinkClick.aspx?fileticket=WBtQtdS0Azk=>. [July 26, 2015].

Department of Education. 2004. White Paper 7. White Paper on e-Education. Transforming Learning and Teaching through Information and Communication Technology. Notice 1869 of 2004. [Online]. Available: <http://www.education.gov.za/LinkClick.aspx?fileticket=0w%2BGatLJpYE%3D&tabid=666&dmid=1861>. [January 21, 2012].

Department of Education. 2008. Support and Adaptations for learners who experience barriers in assessment. [Online]. Available: <https://www.google.co.za/search?q=SUPPORT+AND+ADAPTATIONS+FOR+LEARNERS+>

WHO+EXPERIENCE+BARRIERS+IN+ASSESSMENTandrlz=1C1AVNG_enZA641ZA641and
doq=SUPPORT+AND+ADAPTATIONS+FOR+LEARNERS+WHO+EXPERIENCE+BARRIE
RS+IN+ASSESSMENTandaqs=chrome..69i57.1028j0j4andsourceid=chromeandes_sm=122andi
e=UTF-8. [March 9, 2014].

Department of Education. 2011. Curriculum and assessment Policy Statement Grades 7-9 Mathematics. Pretoria: Department of Education.

Department of Education. 2011. National policy pertaining to the program and promotion Requirements of the national curriculum statement Grades R - 12. Pretoria: Department of Education.

Department of Education. 2011. National Protocol for Assessment. Pretoria: Department of Education.

DePoy, E., and Gitlin, L. N. 2011. Introduction to Research: Understanding and Applying Multiple Strategies. Elsevier/Mosby.

Dougiamas, M. 2001. Moodle: open-source software for producing internet-based courses. [Online]. Available: <http://moodle.org> [February 18, 2011].

Dougiamas, M., and Taylor, P., 2003. Moodle: Using learning communities to create an open source course management system. [Online]. Available: <http://research.moodle.net/33/1/Moodle%20Using%20Learning%20Communities%20to%20Create.pdf>. [February 18, 2011].

Drigas, A.S., Kouremenos, D., Kouremenos, S., and Vrettaros, J., 2005, July. An e-Learning System for the Deaf people. In *Information Technology Based Higher Education and Training, 2005. ITHET 2005. 6th International Conference on* (pp. T2C-17). IEEE.

Dubinsky, E., 1993. Computers in teaching and learning discrete mathematics and abstract algebra. In *Advanced educational technologies for mathematics and science* (pp. 525-563). Springer Berlin Heidelberg.

Dunn, L., Morgan, C., O'Reilly, M., and Parry, S., 2003. *The student assessment handbook: New directions in traditional and online assessment*. Routledge.

Elbaum, B. 2007. Effects of an oral testing accommodation on the mathematics performance of secondary students with and without learning disabilities. *The Journal of Special Education*, 40(4):218-229.

- Elliott, S. N., McKevitt, B. C., and Kettler, R. J. 2002. Testing Accommodations Research and Decision Making: The Case of "Good" Scores Being Highly Valued but Difficult to Achieve for All Students. *Measurement and Evaluation in Counseling and Development*, 35(3):153-66.
- Elliott, S., and Marquart, A. 2004. Extended time as a testing accommodation: Its effects and perceived consequences. *Exceptional Children*, (70):349-367.
- Eplion, D.M., and Keefe, T.J. 2010. Practical Tips for Preventing Cheating on Online Exams. In Hill, C. 2010. Promoting Academic Integrity in Online Education. [Online]. Available: <http://www.lmunet.edu/factools/ctl/report-promoting-academic-integrity.pdf> [October 07, 2015].
- Ernest, P., 1991. *The Philosophy of Mathematics Education*. Studies in Mathematics Education. The Falmer Press. London.
- Ernest, P., 1993. Constructivism, the psychology of learning, and the nature of mathematics: Some critical issues. *Science and Education*, 2(1), pp.87-93.
- Ernest, P., 1999. Social Constructivism as a Philosophy of Mathematics: Radical Constructivism.
- Eixarch Ferrer, R., Xambó, S., Descamps, S., and Marqucs, D., 2003. WIRIS: An Internet platform for the teaching and learning of mathematics in large educational communities. *Contributions to Science*, 269-276.
- Estela, M. R., Saa, J., and Villalonga, J., 2009. Wiris Quizzes. Assessing mathematics through Moodle quizzes.
- Fals-Borda, O., 1987. The application of participatory action-research in Latin America. *International sociology*, 2(4), pp.329-347.
- Feuerstein, R., Rand, Y., Hoffman, M. B., and Miller, R. 1980. Instrumental Enrichment: An Intervention Programme for Cognitive Modifiability. Glenview, IL: University Park Press.
- Feuerstein, R., Rand, Y., and Rynders, J.E., 1988. *Mediated learning experience* (pp. 59-93). Springer US.
- Feuerstein, R., Rand, Y., and Rynders, J.E., 1988. *Don't accept me as I am: Helping "retarded" people to excel*. Springer US.
- Feuerstein, R., Klein, P.S., and Tannenbaum, A.J. 1994. Mediated learning experience (MLE): Theoretical, psychosocial and learning implications. Tel Aviv: Freud Publishing House Ltd.

- Feuerstein, R., Feuerstein, R., Falik, L.H., and Rand, Y., 2002. Assessing the Cognitive Modifiability of Children and Youth with Down syndrome.
- Feuerstein, R., Falik, L., and Feuerstein, R.S., 2014. *Changing Minds and Brains—The Legacy of Reuven Feuerstein: Higher Thinking and Cognition Through Mediated Learning*. Teachers College Press.
- Fraenkel, J.R., and Wallen, N.E., 1993. *How to design and evaluate research in education*. McGraw-Hill.
- Freire, P., 1970. *Pedagogy of the oppressed*. New York: Seabury Press.
- Frostad, P.1999. Deaf children's use of cognitive strategies in simple arithmetic problems. *Educational Studies in Mathematics*, 40(2):129-153.
- Fuchs, L. S., Fuchs, D., and Capizzi, A. M. 2005. Identifying appropriate test accommodations for students with learning disabilities. *Focus on Exceptional Children*, 37(6):1-8. [Online]. Available:
http://www.doe.virginia.gov/special_ed/disabilities/learning_disability/learning_disabilities_guidelines.pdf. [June 13, 2015].
- Garfield, J.B. 1994. Beyond testing and Grading: Using Assessment to improve student learning. *Journal of Statistics Education*. 2(1). [Online]. Available:
<http://www.amstat.org/publications/jse/v2n1/garfield.html>. [April 10, 2015].
- García, A., García, F., Del Rey, Á. M., Rodríguez, G., and De La Villa, A., 2014. Changing assessment methods: New rules, new roles. *Journal of Symbolic Computation*, 61:70-84.
- Garner, B.K., 2007. *Getting to "got it!" helping struggling students learn how to learn*. ASCD.
- Gaster, L., and Clark, C., 1995. *A Guide to Providing Alternate Formats*.
- Gay, LR. 1996. *Educational Research: Competencies for Analysis and Application*. New Jersey: Englewood Cliffs.
- GeoGebra. 2015. [Online]. Available: <https://www.geogebra.org/about>. [April 10, 2015].
- Gergen, K.J., 1985. The social constructionist movement in modern psychology. *American psychologist*, 40(3), p.266.
- Gillis, A., and Jackson, W., 2002. *Research methods for nurses: Methods and interpretation*. Philadelphia: F.A. Davis Company.

- Goldin, G.A., 1990. Chapter 3: Epistemology, constructivism, and discovery learning in mathematics. *Journal for Research in Mathematics Education. Monograph*, 4, pp.31-210.
- Golubski, C., Navarrete, C., and Azua, E., 2013. Improving student outcomes in distance learning mathematics classes. In *Frontiers in Education Conference, 2013 IEEE* (pp. 1396-1398). IEEE.
- Gordon, R. P., and Stump, K. 1996. Assessment of individuals with hearing impairments: Equity in testing procedures and accommodations. *Measurement and Evaluation in Counseling and Development*, 29(2):111–118.
- Graham, C. R., and Misanchuk, M., 2005. Computer-Mediated Learning Groups. Benefits and challenges of using group work in online learning environments.
- Grant, S. 2007. Learning through 'being' and 'doing'. *Action Research*. 5, 265-274.
- Gray, E., and Tall, D., 1991. Duality, ambiguity, and flexibility in successful mathematical thinking. In *PME CONFERENCE* (Vol. 2, pp. 72-79). THE PROGRAM COMMITTEE OF THE 18TH PME CONFERENCE.
- Greenberg, K.H., 2005. *The cognitive enrichment advantage teacher handbook*. KCD Harris & Associates Press.
- Greenwood, D.J., Whyte, W.F., and Harkavy, I., 1993. Participatory action research as a process and as a goal. *Human Relations*, 46(2), pp.175-192.
- Hamayan, E. V. 1995. Approaches to alternative assessment. *Annual Review of Applied Linguistics*, (15):212-226.
- Hammersley, M. 2013. *What is Qualitative Research?* Research Methods Series. Bloomsbury Academic. London. UK.
- Hess, K., 2006. Exploring cognitive demand in instruction and assessment. *National Center for the Improvement of Educational Assessment, Dover NH*. Retrieved from http://www.nciea.Org/publications/DOK_ApplyingWebb_KH08.Pdf.
- Hess, K.K., Jones, B.S., Carlock, D., and Walkup, J.R., 2009. Cognitive Rigor: Blending the Strengths of Bloom's Taxonomy and Webb's Depth of Knowledge to Enhance Classroom-Level Processes. *Online Submission*.

- Honebein, P.C., 1996. Seven goals for the design of constructivist learning environments. *Constructivist learning environments: Case studies in instructional design*, pp.11-24.
- Huertas Sánchez, M. A. 2007. Interactive Calculus in a Virtual Learning Environment. *Elearning*.
- Hung, D., 2001. Theories of learning and computer-mediated instructional technologies. *Educational Media International*, 38(4):281-287.
- Individuals with Disabilities Education Act, (IDEA), 1997. [Online]. Available: <http://www2.ed.gov/legislation/FedRegister/finrule/1999-2/062499a.pdf>. [March 16, 2015].
- Individuals with Disabilities Education Act (IDEA). 2004. [Online]. Available: <http://idea.ed.gov/explore/home>. [February 12, 2015].
- Individuals with Disabilities Education Improvement Act, (IDEIA), 2004. [Online]. Available: <http://idea.ed.gov/download/statute.html>. [March 12, 2015].
- Itmazi, J.A., and Megias, M.G., 2008. Using Recommendation Systems in Course Management Systems to recommend Objects. *Int. Arab J. Inf. Technol*, 5(3):234-240.
- JAVA, 2016. What is JAVA? [Online]. Available: https://java.com/en/download/faq/whatis_java.xml. [March 1, 2013].
- Jewitt, C., Kress, G., Ogborn, J., and Tsatsarelis, C., 2001. Exploring learning through visual, actional and linguistic communication: The multimodal environment of a science classroom. *Educational Review*, 53(1):5-18.
- Jewitt, C., 2003. Re-thinking assessment: Multimodality, literacy, and computer-mediated learning. *Assessment in education: Principles, policy, and practice*, 10(1):83-102.
- Jewitt, C., 2004. Multimodality and new communication technologies. *Discourse and technology: Multimodal discourse analysis*, 184-195.
- Johnson, B., and Christensen, L. 2000. Educational research: quantitative and qualitative approaches. Boston: Allyn and Bacon.
- Johnson, M. J., 2001. Mediation strategies for deaf students: Implementing Feuerstein's instrumental enrichment to address cognitive deficits. *Mediation strategies for deaf students: Implementing Feuerstein's instrumental enrichment to address cognitive deficits*.

Jonassen, D.H., 1992. What are cognitive tools? In *Cognitive tools for learning* (pp. 1-6). Springer Berlin Heidelberg.

Jonassen, D.H., 1994. Technology as cognitive tools: Learners as designers. *ITForum Paper, 1*, pp.67-80.

Jonassen, D., Davidson, M., Collins, M., Campbell, J., and Haag, B. B., 1995. Constructivism and computer-mediated communication in distance education. *American journal of distance education*, 9(2):7-26.

Jonassen, D.H., 2004. LEARNING WITH TECHNOLOGY: USING COMPUTERS AS COGNITIVE TOOLS.

Jonassen, D.H., Carr, C., and Yueh, H.P., 1998. Computers as mindtools for engaging learners in critical thinking. *TechTrends*, 43(2), pp.24-32.

Kalchman, M., and Koedinger, K.R., 2005. In Branford, J.D., and Donovan, S.M., 2005. How students learn: history, mathematics, and science in the classroom. *National Academies Press, Washington*.

Kampfer, S. H., Horvath, L. S., Kleinert, H. L., and Kearns, J. F. 2001. Teacher's perceptions of one state's alternate assessment: implications for practice and preparation. *Exceptional Children*, 67(3):361-374.

Kelly, R. R., and Mousley, K. 1999. Solving math problems. What is the performance of deaf college students? *NTID Research Bulletin*, 4(3):1.

Kelly, R. R., Lang, H.G., and Pagliaro, C. M. 2003. Mathematics word problem-solving for deaf students: A survey of practices in grades 6-12. *Journal of Deaf Studies and Deaf Education*, 8(2):104-119.

Kelly, P. J. 2005. Practical suggestions for community interventions using participatory action research. *Public Health Nursing*, 22(1):65-73.

Kemmis, S., 2008. Critical theory and participatory action research. *The SAGE handbook of action research: Participative inquiry and practice*, 2, pp.121-138.

- Khairiree, K. 2010. A Study of Constructivist in Mathematics in Virtual Class with Moodle and Geometer's Sketchpad. [Online]. Available: http://atcm.mathandtech.org/EP2011/invited_papers/3272011_19339.pdf [February 12, 2013].
- Khullar, S., and Tyagi, A. 2014. The role of student-teacher relationship in educational adjustment and self-esteem of fifth, sixth and seventh-grade students. *Indian Journal of Health and Wellbeing*, 5(12):1472.
- Kidd, D. H., and Lamb, C. E. 1993. Mathematics Vocabulary and the Hearing-Impaired Student: An Anecdotal Study. *Focus on Learning Problems in Mathematics*, 15(4):44-52.
- Kidd, D. H., Madsen, A. L., and Lamb, C. E. 1993. Mathematics vocabulary: Performance of residential deaf students. *School Science and Mathematics*, 93(8):418-421.
- Kim, B., 2001. Social constructivism. *Emerging perspectives on learning, teaching, and technology*, 1(1):16.
- Kim, J. S., 2005. The effects of a constructivist teaching approach on student academic achievement, self-concept, and learning strategies. *Asia pacific education review*, 6(1):7-19.
- King, A., 1994. Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American educational research journal*, 31(2), pp.338-368.
- Kiplinger, V.L., Haug, C.A., and Abedi, J., 2000. Measuring Math--Not Reading--on a Math Assessment: A Language Accommodations Study of English Language Learners and Other Special Populations.
- Kleiner, C., and Lord, M., 1999. The cheating game: A Cross-national exploration of business students' attitudes, perceptions, and tendencies toward academic dishonesty. *Journal of Education for Business*. 47(4):38-42.
- Knuth, E.J. 2000. Understanding connections between equations and graphs. *The Mathematics Teacher*, 93(1): 48-53.
- Koehler, M., and Mishra, P., 2009. What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education*, 9(1), pp.60-70. [Online]. Available: <http://www.citejournal.org/articles/v9i1general1.pdf>. [April 28, 2016].
- Kokol-Voljc, V. 1999. Exam Questions When Using CAS for School Mathematics Teaching. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED445911.pdf> [September 01, 2015].

- Kothari, C.R. 2004. *Research methodology. Methods and Techniques*. New Age International (P) Limited, Publishers.
- Kozulin, A., and Presseisen, B.Z., 1995. Mediated Learning Experience and Psychological Tools: Vygotsky's and Feuerstein's Perspective in a Study of Student Learning.
- Kozulin, A., Feuerstein, R., and Feuerstein, R., 2006. Mediated learning experience paradigm in teacher training.
- Krathwohl, D.R., 2002. A revision of Bloom's taxonomy: An overview. *Theory into practice*, 41(4), pp.212-218.
- Kumar, D., and Wilson, C. L. 1997. Computer technology, science education, and students with learning disabilities. *Journal of Science Education and Technology*, 6(2): 155–160.
- Lane, S. 1999. Validity evidence for assessments. Paper presented at the Edward F. Reidy Interactive Lecture Series, The National Center for the Improvement of Educational Assessment, Providence, RI. [Online]. Available: http://www.nciea.org/publications/ValidityEvidence_Lane99.pdf. [June 13, 2015].
- Lewandowski, L. J., Lovett, B. J., Parolin, R., Gordon, M., and Coddling, R. S. 2007. Extended time accommodations and the mathematics performance of students with and without ADHD. *Journal of Psychoeducational Assessment*, 25(1):17-28.
- Lewis, M.E., 2004. A teacher's schoolyard tale: Illuminating the vagaries of practicing participatory action research (PAR) pedagogy. *Environmental Education Research*, 10(1), pp.89-114.
- Lindstrom, J. H. 2010. Mathematics assessment accommodations: Implications of differential boost for students with learning disabilities. *Intervention in School and Clinic*, 46(1):5-12.
- Loeterman, M., Paul, P. V., and Donahue, S., 2002. Reading and deaf children. *Reading Online*, 5(6):1-18.
- Lorenzetti, J.P. 2010. Remote Proctoring: Key to Secure Exam Administration? [Online]. Available: <http://www.lmunet.edu/factools/ctl/report-promoting-academic-integrity.pdf> [October 07, 2015].

- Lowrey, K. A., Drasgow, E., Renzaglia, A., and Chezan, L. 2007. The impact of Alternate Assessment on Curricula for Students with Severe Disabilities Purpose Driven or Process Driven? *Assessment for Effective Intervention*, 32(4):244-253.
- Lynch, M.M., 2001. Effective student preparation for online learning. *The Technology Source*, 6.
- MacDonald, C. 2012. Understanding participatory action research: a qualitative research methodology option. *The Canadian Journal of Action Research*, 13(2):34-50.
- Maclure, R., and Bassey, M. 1991. "Participatory action research in Togo: An inquiry into maize storage systems". In W.F. Whyte (Ed.) *Participatory action research*, pp. 190-209. Newbury Park: Sage Publications.
- Maihoff, N. A., Bosso, E., Zhang, L., Fischgrund, J., Schulz, J., Carlson, J., et al. 2000. The effects of administering an ASL signed standardized test via DVD player/television and by paper-and-pencil: A pilot study. *Dover: Delaware Department of Education*. [Online]. Available: <http://www.doe.k12.de.us/aab/files/Atch9.pdf>. [May 31, 2015].
- Malaysian Examination Board, Ministry of Education. 2004. Pupil Achievement comparison with Hearing Assessment Forms Using SIBKOM, Direct Teljerrahan Group, and plain form.
- Mann, R. 2004. The influence of data-collection devices on student understanding of the concept of function. Western Illinois University. [Online] Available: http://www.icte.org/T01_Library/T01_240.pdf. [April 4, 2015].
- Marais, E., Argles, D., and von Solms, B., 2006. Security issues specific to e-assessments. *The International Journal for Infonomics*.
- Marschark, M., 1997. *Raising and educating a deaf child*. Oxford University Press.
- Marshall, C., and Rossman, G.B., 2015. *Designing qualitative research*. Sage publications.
- Martin-Blas, T., and Serrano-Fernandez, A., 2009. The role of new technologies in the learning process: Moodle as a teaching tool in Physics. *Computers and Education*, 52(1):35-44.
- Marquès, D., Eixarch, R., Casanellas, G., Martínez, B., and Smith, T. J., 2006. WIRIS OM tools: a semantic formula editor.
- Marshall, M. N. 1996. Sampling for qualitative research. *Family practice*, 13(6):522-526.
- McIntyre, A. 2008. *Participatory Action Research*. Sage Publications. California.

- McIntyre, A. 2002. Women researching their lives: exploring violence and identity in Belfast, the North of Ireland. *Qualitative Research*, 2(3):387-409.
- McMurtry, K. 2001. E-cheating: Combating a 21st Century Challenge. *T.H.E. Journal*. [Online]. Available: <http://www.delta.edu/lic/libraryresearch/e-cheating.aspx> [October 06, 2015].
- McTaggart, R., 1991. Principles for participatory action research. *Adult Education Quarterly*, 41(3), pp.168-187.
- Mead, G.H., 1934. *Mind, self, and society* (Vol. 111). University of Chicago Press: Chicago.
- Moodle, 2015. Moodle 2.7 Release notes. [Online]. Available: https://docs.moodle.org/dev/Moodle_2.7_release_notes. [March 1, 2015].
- Moodle, 2016. Moodle 2.7.1 Release notes. [Online]. Available: https://docs.moodle.org/dev/Moodle_2.7_release_notes. [January 1, 2016].
- Moon, J. L. 2013. Comparability of Online and Paper/Pencil Mathematics Performance Measures. [Online]. Available: <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1169&context=cehdsdiss> . [October 3, 2015].
- Moore, D. F., 2000. Educating the deaf: Psychology, principles, and practices (2nd Ed.). Boston: Houghton Mifflin Company.
- Moore, D. F. 2002. The law of unexpected consequences. *American Annals of the Deaf*, 147(2):84–87.
- Mora, Á. Mérida, E., and Eixarch, R., 2011. Random learning units using WIRIS quizzes in Moodle. *International Journal of Mathematical Education in Science and Technology*, 42(6):751-763.
- Moskal, B. M., and Leydens, J. A., 2000. Scoring rubric development: Validity and reliability. *Practical assessment, research, and evaluation*, 7(10):71-81.
- Mouton, J. 2012. *How to succeed in your Master's and Doctoral studies. A South African Guide and Resource Book*. Van Schaik Publishers. Pretoria.
- Mueller, V., and Hurtig, R., 2010. Technology-enhanced shared reading with deaf and hard-of-hearing children: The role of a fluent signing narrator. *Journal of Deaf Studies and Deaf Education*, 15(1):72-101.

- Myklebust, H., 1964. *The psychology of deafness*. Sensory Deprivation, Learning, and Adjustment. Grune and Stratton. New York.
- Myklebust, H., 1997. *The psychology of deafness*. In Marschark, M. *Psychological Development of Deaf Children*. New York. *The Volta Review*, 99(3):163-170.
- Naismith, L, and Sangwin, C.J. 2004. Computer algebra based assessment of mathematics online. In Proceedings of the 8th CAA Conference 2004, 6th and 7th July. The University of Loughborough, UK.
- National Council of Teachers of Mathematics. 2000. *Principles and standards for school mathematics*. Reston, VA: NCTM.
- No Child Left Behind Act* of 2001, (NCLB). [Online]. Available: <https://www2.ed.gov/nclb/overview/intro/execsumm.pdf>. [May 1, 2015].
- National University of Malaysia, Malaysian Examination Board. 2008. E - Voice alternative assessment: Special education students with learning disabilities in Malaysia. [Online]. Available: <http://english.astroawani.com/topic/Malaysian+Examination+Board> [January 10, 2015].
- Nunes, T., and Moreno, C. 1998. Is hearing impairment a cause of difficulties in learning mathematics? In C. Donlan (ed.), *the development of mathematical skills*. Hove, Britain: Psychology Press. 227–254.
- Nunes, T., and Moreno, C. 1998. The signed algorithm and its bugs. *Educational Studies in Mathematics*. 35(1):85-92.
- Nunes, T., and Moreno, C. 2002. An Intervention Program for Promoting Deaf Pupils' Achievement in Mathematics. *Journal of Deaf Studies and Deaf Education*. 7(2):120-133.
- Nyden, P., Figert, A., Shibley, M., and Burrows, D. 1997. Building community: Social science in action. Thousand Oaks, CA: Pine Forge Press.
- O'Callaghan, B., R. 1998, "Computer-intensive algebra and students' conceptual knowledge of functions", *Journal for Research in Mathematics Education*, vol. 29, no. 1, pp. 21.
- O'Connor, H., and Gibson, N., 2003. A step-by-step guide to qualitative data analysis. *Pimatisiwin: A Journal of Indigenous and Aboriginal Community Health*, 1(1):63-90.

- Ohio Department of Education, 2015. Alternate Assessment for Students with Significant Cognitive Disabilities. Directions for Administration Manual. [Online]. Available: http://oh.portal.airast.org/oh_alt/wp-content/uploads/2014/09/SP15_AASCD_Directions_for_Administration_Manual1.pdf. [June 13, 2015].
- Olt, M. R. 2002. Ethics and distance education: Strategies for minimizing academic dishonesty in online assessment. *Online journal of distance learning administration*, 5(3).
- Ozcelik, E., and Yildirim, S., 2005. Factors influencing the use of cognitive tools in web-based learning environments. *Quarterly Review of Distance Education*, 6(4), pp.295-308.
- Olsen, L. 2005. The impact of Paper-and-Pencil, Online Testing Is Compared.
- Pagliaro, C. M., and Ansell, E. 2002. Story problems in the deaf education classroom: Frequency and mode of presentation. *Journal of Deaf Studies and Deaf Education*, 7(2):107-119. [Online]. Available: <http://www.biomedsearch.com/nih/Story-problems-in-deaf-education/15451879.html> [2013, May 12].
- Pagliaro, C. M. 2006. Mathematics education and the deaf learner. In *Deaf learners: Developments in curriculum and instruction*. (Eds.) Moores, D. F., and Martin, D. S. Gallaudet University Press. 29-40.
- Pan, G. and Bonk, C.J., 2007. The emergence of open-source software in China. *The International Review of Research in Open and Distributed Learning*, 8(1).
- Panagiotakopoulos, C., and Koustourakis, G. 2001. Dealing with 1st-year university student's computer anxiety. *Themes in Education*, 2(1):35-46.
- Panitz, T., 1999. Collaborative versus Cooperative Learning: A Comparison of the Two Concepts Which Will Help Us Understand the Underlying Nature of Interactive Learning. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED448443.pdf> [August 30, 2015].
- Parshall, C.G., and Harmes, J.C., 2007. Designing templates based on a taxonomy of innovative items. In *Proceedings of the 2007 GMAC Conference on Computerized Adaptive Testing*. <http://www.Psych.umn.Edu/psylabs/catcentral/pdf%20files/cat07.Pdf>.
- Parshall, C.G., and Harmes, J.C., 2014. Improving the quality of innovative item types: Four tasks for design and development. *Association of Test Publishers*, 10(1), pp.1-20.

Paulsen, C.A., and Dailey, D., 2002. A Guide for Education Personnel: Evaluating a Program or Intervention: Elementary and Middle School Technical Assistance Centre (EMSTAC). American Institute for Research. Washington, DC. [Online]. Available: <http://www.emstac.org/resources/eval.pdf>. [March 17, 2014].

Piaget, J., 1951. *The Psychology of Intelligence*. London: Routledge and Kegan Paul Ltd.

Ping, L. C., and Swe, K. M., 2004. Engaging junior college students in computer-mediated lessons using scaffolding strategies. *Journal of Educational Media*, 29(2):97-112.

Pea, R.D., 1987. Cognitive technologies for mathematics education. *Cognitive science and mathematics education*, pp.89-122.

Pepper, D. 2007. Assessment for disabled students: an international comparison. QCA briefing document. International Unit Regulation and Standards Division. [Online]. Available: http://dera.ioe.ac.uk/7174/1/Assessment_disabled_international_briefing.pdf. [March 15, 2015].

Petit, M., and Hess, K., 2006. Applying Webb's Depth of Knowledge and NAEP levels of complexity in mathematics.

Prebianca, G. V., Junior, S., and Finardi, K. R., 2014. Analysis of an educational software for language learning: insights from the Theory of Structural Cognitive Modifiability and Human-Computer Interaction. *DELTA: Documentação de Estudos em Lingüística Teórica e Aplicada*, 30(1):95-114.

Philosophy of Moodle. 2015. [Online]. Available: <http://docs.moodle.org/27/en/Philosophy> [January 10, 2013].

Pihlap, S., 2014. Opinions of Teachers on the Use of the WIRIS Computer Algebra System for Teaching and Learning Mathematics. RandE-SOURCE.

Pitcher, N., Goldfinch, J., and Beevers, C., 2002. Aspects of computer-based assessment in mathematics. *Active learning in higher education*, 3(2):159-176.

Pliskhin, R. (Ed). 2011. For computer-based testing, the future is here. *Educational Testing Service (ETS) Innovations*, 11(1):6-7.

Peltenburg, M., Van Den Heuvel-Panhuizen, M., and Doig, B. 2009. Mathematical power of special-needs pupils: An ICT-based dynamic assessment format to reveal weak pupils' learning potential. *British Journal of Educational Technology*, 40(2):273-284.

Qi, S., and Mitchell, R. E. 2007. Large-scaled academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Qi, S., and Mitchell, R. E. 2012. Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Journal of Deaf Studies and Deaf Education*, 17(1):1–18.

Quenemoen, R., Thompson, S., and Thurlow, M. 2003. Measuring academic achievement of students with significant cognitive disabilities: Building understanding of alternate assessment scoring criteria (Synthesis Report No. 50). Minneapolis, MN: The University of Minnesota, National Center on Educational Outcomes. [Online]. Available: <http://www.cehd.umn.edu/NCEO/OnlinePubs/Synthesis50.html>. [April 27, 2015].

Rahman, M.A., 2008. Some trends in the praxis of participatory action research. *The Sage handbook of action research: Participative inquiry and practice*, pp.49-62.

Reason, P., and Bradbury, H., 2008. *The Sage Handbook of Action Research: Participative Inquiry and Practice*. Sage Publications. Los Angeles.

Ramos, J., Trenas, M. A., Gutiérrez, E., and Romero, S., 2013. E-assessment of Matlab assignments in Moodle: Application to an introductory programming course for engineers. *Computer Applications in Engineering Education*, 21(4):728-736.

Reitsma, P., 2008. Computer-based exercises for learning to read and spell by deaf children. *Journal of deaf studies and deaf education*, enn031.

Republic of South Africa. Department of Education. 2001. Education White Paper 6. Special needs education. Building an inclusive education and training system. Government Gazette no. 22524, 27 July.

Republic of South Africa. Department of Education. 2011. The Curriculum and Assessment Policy Statement Grades R-12. Government Notice No. 784 and No. 785, Government Gazette No. 33528, 3 September 2010.

Republic of South Africa. Department of Education. 2012. National Protocol for Assessment Grades R – 12. Government Notice No. 1115 and No. 1116, Government Gazette No. 36042 of 28 December 2012.

Republic of South Africa. Department of Education. National policy pertaining to the program and promotion requirements of the National Curriculum Statement Grades R – 12. Government Notice No. 1115 and No. 1116, Government Gazette No. 36042, 28 December 2012.

Republic of South Africa. Department of Basic Education. 2011. National Protocol for Assessment Grades R-12. [Online]. Available:

<http://www.education.gov.za/LinkClick.aspx?fileticket=BUB00bmth1I%3dandtabid=419andmid=2313>. [January 2014, 10].

Republic of South Africa. Department of Basic Education. 2011. National Policy Pertaining to the Programme and Promotion Requirements of the National Curriculum Statement Grades R – 12. [Online]. Available:

<http://www.education.gov.za/LinkClick.aspx?fileticket=spw4luemhQQ%3dandtabid=419andmid=2313>. [January 2014, 12].

Republic of South Africa. Department of Basic Education. 2011. Curriculum and Assessment Policy Statement Grades 1-3 Mathematics. [Online]. Available:

<http://www.education.gov.za/LinkClick.aspx?fileticket=HdHiU122n1w%3dandtabid=571andmid=1562>. [January 13, 2013].

Republic of South Africa. Department of Basic Education. 2011. Curriculum and Assessment Policy Statement Grades 4-6 Mathematics. [Online]. Available:

<http://www.education.gov.za/LinkClick.aspx?fileticket=dr7zg3CFCr8%3Dandtabid=572andmid=1568>. [January 13, 2013].

Republic of South Africa. Department of Basic Education. 2011. Curriculum and Assessment Policy Statement Grades 7-9 Mathematics. [Online]. Available:

<http://www.education.gov.za/LinkClick.aspx?fileticket=uCNqOwfGbmc%3dandtabid=573andmid=1629>. [January 13, 2013].

Republic of South Africa. Department of Basic Education. 2011. Guidelines for responding to learner diversity in the classroom through Curriculum and assessment policy statements.

[Online]. Available: www.thutong.doe.gov.za/InclusiveEducation. [June 02, 2015].

Republic of South Africa. Department of Basic Education. 2014. Policy on Assessment for Learners who Experience BTL and Assessment. [Online]. Available:

<http://www.thutong.doe.gov.za/Default.aspx?alias=www.thutong.doe.gov.za/inclusiveeducation>. [June 02, 2015].

Republic of South Africa. Department of Basic Education. 2014. Policy on Screening, Identification, and Support. [Online]. Available: <http://www.education.gov.za/Portals/0/Documents/Policies/SIAS%20Final%2019%20December%202014.pdf?ver=2015-02-24-131207-203>. [June 02, 2015].

Republic of South Africa. Department of Basic Education. 2014. Curriculum and Assessment Policy Statement Grades 7-9 South African Sign Language. Home Language. [Online]. Available: <http://www.education.gov.za/LinkClick.aspx?fileticket=kexx5oS071U%3dandtabid=420andmid=2373>. [January 13, 2013].

Republic of South Africa. Department of Basic Education. Schooling 2025: Action Plan for improving schooling Basic Education in South Africa. [Online]. Available: <http://www.educationthatpaysforitself.com/documents/Schooling%202025.pdf>. [May 12, 2015].

Republic of South Africa. Department of Basic Education. Draft Policy on Screening, Identification, Assessment, and Support. [Online]. Available: <http://www.gov.za/sites/www.gov.za/files/SIAS%20Revised%20Final%20for%20Comment.pdf>. [February 12, 2015].

Rice, W., 2011. *Moodle 2.0 E-Learning Course Development*. Packt Publishing Ltd.

Rich, P., 1999. Giving and Receiving Feedback. [Online]. Available: <http://www.selfhelpmagazine.com/articles/giving-feedback#sthash.QVzdVDBi.dpbs> [October 11, 2015].

Ritchie, J., and Lewis, J. 2003. *Qualitative Research Practice: A guide for Social Science Students and Researchers*. Sage Publications. London.

Ritchie, J., Lewis, J., Nicholls, C. M., and Ormston, R. (Eds.). 2013. *Qualitative research practice: A guide for social science students and researchers*. Sage.

Roach, A. T., Elliott, S. N., and Webb, N. L. 2005. Alignment of an Alternate Assessment with State Academic Standards Evidence for the Content Validity of the Wisconsin Alternate Assessment. *The Journal of Special Education*, 38(4):218-231.

- Roeber, E. 2002. Setting standards on alternate assessments (Synthesis Report 42). Minneapolis: The University of Minnesota, National Center on Educational Outcomes. [Online]. Available: <http://www.cehd.umn.edu/nceo/onlinePubs/Synthesis42.html>. [June 12, 2015].
- Rose, S., Barkmeier, L., Landrud, S., Klansek-Kyllo, V., McAnally, P., Larson, K.G., and Hoekstra, V. 2008. Resources for Assessment of Students Who Are Deaf and Hard of Hearing. [Online]. Available: https://webcache.googleusercontent.com/search?q=cache:oSUgaVGmXP8J:https://education.state.mn.us/mdeprod/idcplg%3FIdcService%3DGET_FILE%26dDocName%3D004331%26RevisionSelectionMethod%3DlatestReleased%26Rendition%3Dprimary+&cd=1&hl=en&ct=clnk&gl=za. [January 12, 2015].
- Rubin, H.J., and Rubin, I.S., 2011. *Qualitative interviewing: The art of hearing data*. Sage.
- Russell, M., Kavanaugh, M., Masters, J., Higgins, J., and Hoffmann, T. 2009. Computer-based signing accommodations: Comparing a recorded human with an avatar. *Journal of Applied Testing Technology*, 10(3). [Online]. Available: http://www.testpublishers.org/assets/documents/computer_based.pdf. [May 31, 2015].
- Ryba, K., Selby, L., and Nolan, P. 1995. Computers empower students with special needs. *Educational Leadership*, 53(2):82–84.
- Sangwin, C. 2004. Assessing mathematics automatically using computer algebra and the internet. *Teaching Mathematics and its Applications*, 23(1), 1-14.
- Salomon, G., Perkins, D.N., and Globerson, T., 1991. Partners in cognition: Extending human intelligence with intelligent technologies. *Educational researcher*, 20(3), pp.2-9.
- Sandford, B. A., and Hsu, C. C. 2013. Alternative assessment and portfolios: review, reconsider and revitalize. *International Journal of Social Science Studies*, 1(1):215-221.
- Sandene, B., Horkay, N., Bennett, R. E., Allen, N., Braswell, J., Kaplan, B., and Oranje, A., 2005. Online Assessment in Mathematics and Writing: Reports from the NAEP Technology-Based Assessment Project, Research and Development Series. NCES 2005-457. *National Center for Education Statistics*.
- Sangwin, C., 2004. Assessing mathematics automatically using computer algebra and the internet. *Teaching Mathematics and its Applications*, 23(1):1-14.

- Santrock, J.W. 2011. *Educational Psychology*. 5th edition. New York: McGraw-Hill.
- Sarri, R.C., and Sarri, C., 1993. Organizational and community change through participatory action research. *Administration in Social Work*, 16(3-4), pp.99-122.
- Schirmer, B. 2001. Psychological, social, and educational dimensions of deafness. Needham Heights, MA: Allyn and Bacon.
- Schriver, K.A. 1997. Dynamics in document design. John Wiley & Sons. [Online]. Available: <https://pantherfile.uwm.edu/alred/www/pdf/schriver-dynamics.pdf> [March 20, 2016].
- Shulman, L.S., 1986. Those who understand: Knowledge growth in teaching. *Educational researcher*, 15(2), pp.4-14.
- Schunk, D.H., 2011. Learning Theories. An Educational Perspective. Pearson. New York.
- Schunk, D.H., 2012. *Learning Theories: An Educational Perspective*. Pearson. Boston.
- Singleton, C. 2004. Computer-based assessment. In L. Florian and J. Hegarty (Eds), ICT and special educational needs (pp. 46–61). Berkshire: Open University Press.
- Seabi, J., and Amod, Z., 2009. Effects of mediated intervention on cognitive functions: A pilot study with Grade 5 learners at a remedial school. *Australian Journal of Learning Difficulties*, 14(2):185-198.
- Seabi, J., Cockcroft, K., and Fridjhon, P., 2009. Effects of mediated learning experience, tutor support and peer collaborative learning on academic achievement and intellectual functioning among college students. *Journal of Psychology in Africa*, 19(2):161-167.
- Seng, S., 1997. Using Mediated Learning Experiences to Enhance Children's Thinking. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED406052.pdf>. [July 8, 2015].
- Seng, T. O., 2003. Mediated learning and pedagogy: Applications of Feuerstein's theory in twenty-first-century education. *React*, 53. [Online]. Available: <https://repository.nie.edu.sg/bitstream/10497/4088/1/2003Issue1.pdf#page=56>. [July 8, 2015].
- Shavelson, R.J., 1974. Methods for examining representations of a subject-matter structure in a student's memory. *Journal of Research in Science Teaching*, 11(3), pp.231-249.
- Skuy, M., Gewer, A., Osrin, Y., Khunou, D., Fridjhon, P., and Rushton, J. P., 2002. Effects of mediated learning experience on Raven's matrices scores of African and non-African university students in South Africa. *Intelligence*, 30(3):221-232.

Stacey, K., 2003. Using computer algebra systems in secondary school mathematics: Issues of curriculum, assessment, and teaching. In *Proceedings of the 8th Asian technology conference in mathematics* (pp. 40-54).

South African Qualifications Framework Authority. (SAQA). 1995. [Online]. Available: <http://www.unisa.ac.za/contents/projects/docs/saqa%2058%20of%201995.pdf>. [February 10, 2015].

South African Qualification Authority. 2001. National Qualifications Framework. [Online]. Available: <http://www.saqa.org.za/docs/guide/2001/assessment.pdf>. June 6, 2105.

Sun, P.C., Tsai, R.J., Finger, G., Chen, Y.Y. and Yeh, D., 2008. What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & education*, 50(4), pp.1183-1202.

Tessmer, M. 1993. *Planning and Conducting Formative Evaluations: Improving the Quality of Education and Training*. Kogan Page. London. Philadelphia.

Thompson, S. J., and Thurlow, M. L. 2000. *State alternate assessments: Status as IDEA alternate assessment requirements take effect* (Synthesis Report No. 35). Minneapolis, MN: the University of Minnesota, National Center on Educational Outcomes. [Online]. Available: <http://education.umn.edu/NCEO/OnlinePubs/Synthesis35.html>. [May 2, 2015].

Thompson, S.J., Johnstone, C.J., and Thurlow, M.L., 2002. Universal Design Applied to Large-Scale Assessments. Synthesis Report. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED467721.pdf> [June 8, 2015].

Thompson, S., and Thurlow, M. 2003. 2003 state special education outcomes: Marching on. Minneapolis: The University of Minnesota, National Center on Educational Outcomes. [Online]. Available: <http://www.cehd.umn.edu/NCEO/OnlinePubs/2003StateReport.htm>. [June 13, 2015].

Thompson, S., Thurlow, M. and Malouf, D.B., 2004. Creating better tests for everyone through universally designed assessments. *Association of Test Publishers*, 6(1):1-15.

Thompson, S. J., Morse, A. B., Sharpe, M., and Hall, S. 2005. Accommodations manual. How to select, administer, and evaluate the use of accommodations for instruction and assessment of students with disabilities (Second Ed.). Washington, DD: The Council of Chief State School

Officers. [Online]. Available:

<http://www.cehd.umn.edu/NCEO/OnlinePubs/AccommodationsManual.pdf>. [May 10, 2015].

Thurlow, M., Lazarus, S.S., Albus, D., and Hodgson, J., 2010. Computer-Based Testing: Practices and Considerations. Synthesis Report 78. *National Center on Educational Outcomes, University of Minnesota*. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED512613.pdf> [January 10, 2015].

Tindal, G., and Ketterlin-Geller, L. R. 2004. Research on Mathematics Test Accommodations Relevant to NAEP Testing. National Assessment Governing Board. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED500433.pdf>. [May 31, 2015].

Todor, O. A., 2013. FEUERSTEIN INSTRUMENTAL ENRICHMENT PROGRAM. Scientific Research and Education in the Air Force-AFASES, 1. [Online]. Available: http://www.afahc.ro/ro/afases/2013/socio/todor_feuerstein.pdf. [July 8, 2015].

Toumasis, C., 1997. The NCTM Standards and the Philosophy of Mathematics. *Studies in Philosophy and Education*. 16, 317-330.

Traxler, C. B. 2000. The Stanford Achievement Test, 9th Edition: National norming and performance standards for deaf and hard of hearing students. *Journal of Deaf Studies and Deaf Education*, 5(4):337–348.

Tsai, C.C., and Huang, C.M., 2002. Exploring students' cognitive structures in learning science: a review of relevant methods. *Journal of Biological Education*, 36(4), pp.163-169.

Tzuriel, D., 2013. Mediated learning experience and cognitive modifiability. *Journal of Cognitive Education and Psychology*, 12(1), pp.59-80.

Umalusi, 2015. Council for Quality Assurance in General and Further Education and Training. [Online]. Available: <http://www.umalusi.org.za>. [March 4, 2016].

United States of America. Department of Education, 2005. Alternate achievement standards for students with the most significant cognitive disabilities. [Online]. Available: <https://www2.ed.gov/policy/elsec/guid/altguidance.pdf>. [June 13, 2015].

Uribe, D., Klein, J. D., and Sullivan, H., 2003. The effect of computer-mediated collaborative learning on solving III-defined problems. *Educational Technology Research and Development*, 51(1):5-19.

- Urquhart, V., 2009. Using Writing in Mathematics to Deepen Student Learning. *Mid-continent Research for Education and Learning (McREL)*.
- Vandeyar, S., and Killen, R. 2003. Has curriculum reform in South Africa really changed assessment practices, and what promise does the revised National Curriculum Statement hold? *Perspectives in Education: Assessment of Change in Education: Special Issue 1(21)*:119.
- Van de Walle, J. A., Karp, K. S., and Bay-Williams, Jennifer M., 2013. Elementary and Middle School Mathematics. Teaching Developmentally (9th).
- Verhage, H., Adendorff, S., Cooper, P., Engel, M., Kasana, Z., le Roux, P., Smith, R., and Williams, E. 2000. The interrelationship between graphs, formula, and tables: exploring the relationship between mathematising and outcomes-based education. *Pythagoras*, 51:37-42.
- Vinuesa, T. S., and Masià, R., 2007. A virtual mathematics learning environment for engineering students. *Interactive Educational Multimedia: IEM*, (14):1-18.
- Von Glasersfeld, E., Constructivism in Education. In: T. Husen and T. N. Postlethwaite, (eds.). 1989. The International Encyclopedia of Education, Supplement Vol.1. Oxford/New York: Pergamon Press, 162–163.
- Von Glasersfeld, E., 1995. A constructivist approach to teaching. In: Steffe L. P. and Gale J. (eds.) Constructivism in education. Erlbaum, Hillsdale: 3–15.
- Von Glasersfeld, E., 1995. *Radical Constructivism: A Way of Knowing and Learning. Studies in Mathematics Education Series: 6*. Falmer Press, Taylor & Francis Inc., 1900 Frost Road, Suite 101, Bristol, PA 19007.
- Vygotsky, L.S., 1978. *Mind in society. The development of the higher psychological processes*. Cambridge, MA: Harvard University Press.
- Vygotsky, L., 1978. The interaction between learning and development. *Readings on the development of children*, 23(3), pp.34-41.
- Walliman, N., 2010. *Research methods: The basics*. Routledge.
- Walker, R., and Delius, G., 2004. Integrating on-line assessment with class-based teaching and learning: a preliminary study of the AiM marking system.

Webb, N.L., 1999. Alignment of Science and Mathematics Standards and Assessments in the Four States. Research Monograph No. 18. [Online]. Available: <http://files.eric.ed.gov/fulltext/ED440852.pdf>. [May 12, 2015].

Western Cape Education Department. 2009. Processes and Procedures for Exemptions and Concessions in grade 9. [Online]. Available: http://wced.school.za/circulars/circulars09/e21_09.html. [May 12, 2015].

Western Cape Education Department. 2016. Management of Assessment Accommodations for learners who experience barriers to learning and assessment: Grades R -12 and for learners who requested immigrant status for assessment purposes: Grades 4 - 12. [Online]. Available: http://wced.pgwc.gov.za/circulars/circulars16/e17_16.html. [June 12, 2016].

Weston, T. J. 2002. The validity of oral accommodation in testing. *NAEP Validity Studies (NVS) Panel*. [Online]. Available: http://www.air.org/sites/default/files/downloads/report/weston_finalrevpdf_0.pdf. [January 19, 2015].

Wild, I., 2009. *Moodle 1.9 Math*. Packt Publishing Ltd.

Willoughby, S.S., 1997. Functions from kindergarten through sixth grade. *Teaching Children Mathematics*, 3, pp.314-318.

Winer, R., Deighton, J., Gupta, S., Johnson, E., Mellers, B., Morwitz, Thomas O'guinn, Arvind Rangaswamy and Sawyer, A., 1997. Choice in computer-mediated environments. *Marketing Letters*, 8(3), 287-296.

WIRIS. 2015. [Online]. Available: <http://www.wiris.com>. [January 10, 2013].

WIRIS. 2015. [Online]. Available: <http://www.wiris.com> [December 1, 2014].

WIRIS. 2016. [Online]. Available: <http://www.wiris.com> [January 10, 2015].

Woodward, J., and Rieth, H. 1997. A historical review of technology research in special education. *Review of Educational Research*, 67(4):503-536.

Whyte, W.F., 1989, September. Advancing scientific knowledge through participatory action research. In *Sociological Forum* (Vol. 4, No. 3, pp. 367-385). Kluwer Academic Publishers-Plenum Publishers.

Whyte, W.F. 1991. *Participatory Action Research*. Newbury Park, CA: Sage Publications.

Xambó, S., Eixarch, R., and Marquès, D., 2002. WIRIS: An Internet platform for the teaching and learning of mathematics in large educational communities. *Contributions to science*, 2(2):269-276.

Yasin, M.H.M., Sahari, N., and Nasution, A.H., 2013. Online Literacy and Mathematics Assessment for Deaf and Hard of Hearing Students. *CREAM. Current Research in Malaysia*. 2(1):65-99.

Zarfaty, Y., Nunes, T., and Bryant, P. 2004. The performance of young deaf children in spatial and temporal number tasks. *Journal of Deaf Studies and Deaf Education*. 9(3):315 – 326.